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2024-2025 Undergraduate Catalog

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www.cmu.edu (http://www.cmu.edu)

Carnegie Mellon University's Undergraduate Catalog is an annual publication that details academic programs and degrees offered, course descriptions, and university policies and services.

While information in this catalog is current as of August 2024, it is subject to change throughout the academic year. Students should consult with their academic department for the most up-to-date information about program requirements. Members of the campus community may direct catalog changes or inquiries to catalog@andrew.cmu.edu. Note that once the PDF of the catalog is final and archived, changes can only be made to the online version.

The next catalog will be published in August 2025; in the interim, new courses will be displayed in the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/), which is published in November and April each year.

Policy Statement

Carnegie Mellon University does not discriminate in admission, employment, or administration of its programs or activities on the basis of race, color, national origin, sex, disability, age, sexual orientation, gender identity, pregnancy or related condition, family status, marital status, parental status, religion, ancestry, veteran status, or genetic information. Furthermore, Carnegie Mellon University does not discriminate and is required not to discriminate in violation of federal, state, or local laws or executive orders.

The university's Discriminatory and Sexual Misconduct Policy *(*https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/*) contains grievance procedures that provide for the prompt and equitable resolution of Complaints alleging any action which would be prohibited by this Policy.*

Inquiries concerning the application of and compliance with this statement should be directed to the Office for Institutional Equity and Title IX, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA 15213, telephone 412-268-7125.

Obtain general information about Carnegie Mellon University by calling 412-268-2000.

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About CMU

Carnegie Mellon is a private, internationally ranked (https://www.cmu.edu/about/rankings.html) research university with programs in areas ranging from science, technology and business, to public policy, the humanities and the arts. More than 16,000 students in the university’s seven schools and colleges benefit from a small student-to-faculty ratio and an education characterized by its focus on creating and implementing solutions for real problems, interdisciplinary collaboration and innovation.

Undergraduate students can pursue majors in six of the university's seven colleges: the College of Engineering, the College of Fine Arts, the Tepper School's business administration program, the Dietrich College of Humanities and Social Sciences, the Mellon College of Science, and the School of Computer Science.

CMU is positioned like never before to meet the challenges of the 21st century. At the intersection of technology and humanity, CMU research, innovation and creativity will continue to guide our future as a world-class university.

As outlined in the Strategic Plan 2025 (http://www.cmu.edu/strategic-plan/), the university will focus on advancing the individual student experience, the broader Carnegie Mellon community experience, and the social impact of Carnegie Mellon throughout the world.

Take a closer look at CMU (p. 7).

Vision & Mission

Vision

Carnegie Mellon University will have a transformative impact on society through continual innovation in education, research, creativity, and entrepreneurship.

Mission

To create a transformative educational experience for students focused on deep disciplinary knowledge; problem solving; leadership, communication, and interpersonal skills; and personal health and well-being.

To cultivate a transformative university community committed to (a) attracting and retaining diverse, world-class talent; (b) creating a collaborative environment open to the free exchange of ideas, where research, creativity, innovation, and entrepreneurship can flourish; and (c) ensuring individuals can achieve their full potential.

To impact society in a transformative way — regionally, nationally, and globally — by engaging with partners outside the traditional borders of the university campus.

Look at Carnegie Mellon

CMU's History

In a letter written in 1900, industrialist and philanthropist Andrew Carnegie offered to give the city of Pittsburgh $1 million in bonds to found a technical institute. The city provided 32 acres of land near Schenley Park, and the institution became known as the Carnegie Technical Schools. According to Carnegie's plans, the institution would train the sons and daughters of working-class families in five schools: Science and Technology, to train draftsmen and engineer's assistants; Fine and Applied Arts, for designers and art workers; Apprentices and Journeymen, for mechanics in manufacturing and construction; and Margaret Morrison Carnegie College, for home economists or secretaries. Within two decades, the Carnegie Technical Schools offered bachelor's, master's and doctoral programs, and fittingly changed its name to the Carnegie Institute of Technology.

In 1967, the trustees of the Mellon Institute and the Carnegie Institute of Technology merged the two institutions and adopted the name Carnegie Mellon University. In 1968, Margaret Morrison Carnegie College closed and the university organized a new College of Humanities and Social Sciences. New graduate-level colleges and schools also flourished, including the Graduate School of Industrial Administration (GSIA), the Heinz College of Public Policy and Management, and the School of Computer Science. As time progressed, new research centers and institutes developed on and off campus in specialties ranging from art conservation to sustainable computing. In 2004, GSIA was renamed the Tepper School of Business after alumnus David A. Tepper.

Over time, the Carnegie Institute of Technology has developed from a regional, technical college into Carnegie Mellon University, a selective, international research university that ranks among the nation's best colleges.

A Unique Educational Experience

The university's diverse community, focus on strong student-faculty ties and commitment to education outside the classroom combine to create a learning environment that is as uniquely Carnegie Mellon as the Tartan plaid on the kilts of its bagpipers.

Carnegie Mellon strives for a campus culture that reflects a fundamental respect for different ways of living, working, and learning so every student has the opportunity to reach their potential.

A Carnegie Mellon education is marked by its strong focus on fundamental and versatile problem-solving skills in a specific discipline, but the university respects and values students' varied talents and interests that often span many specialties. Students can explore more than one field of study while developing the strong professional core that is the hallmark of a Carnegie Mellon education. The university encourages students to expand their thinking in new and exciting dimensions.

CMU's faculty conduct groundbreaking research, create new and exciting art, and contribute to a growing global scholastic community. They are continuously innovating, and the new knowledge they create and the methods they discover routinely benefit classroom learning. Research is a vital component of undergraduate education at Carnegie Mellon. Students can initiate projects of their own or become involved with existing ones on campus.

A Global Impact

In its 115 years, Carnegie Mellon has soared to national and international leadership in higher education and research. A birthplace of innovation since its founding, it continues to be known for innovation, for solving real-world problems and for interdisciplinary collaboration.

Its alumni can be found across the globe — from Tony Award winners to Nobel Prize and Turing Award winners, from CEOs to entrepreneurs, from professors to artists.

In the 2000s, in response to demand for expanded international educational opportunities, Carnegie Mellon began offering degree programs outside of Pittsburgh. Today its global presence includes campuses in Qatar and Silicon Valley, California, more than a dozen degree-granting locations, and more than 20 research partnerships such as Los Angeles, New York City, Washington, D.C., Portugal, and Africa.

Undergraduate Admission

Kristina Wong Davis, Vice Provost for Enrollment Management & Dean of Admission

Location: Warner Hall, 2nd Floor, 5000 Forbes Ave., Pittsburgh, PA 15213
Phone: 412-268-2082
Fax: 412-268-7838
Email: admission@andrew.cmu.edu
www.cmu.edu/admission (http://www.cmu.edu/admission/)

ADMISSION PHILOSOPHY

At Carnegie Mellon, we select our first-year class from a large group of very qualified candidates. We don’t use a calculation to choose who to admit because calculations can’t take into account all the factors we consider when making admission decisions. No single grade, factor, score or activity will automatically gain or deny you admission to Carnegie Mellon. We treat every applicant as an individual, taking great care to make our admission decisions fair, thorough and sensitive. We’re interested in students who can be successful at Carnegie Mellon while taking full advantage of all the university has to offer.

ADMISSION CRITERIA

Our admission process is designed to select a highly talented, diverse undergraduate population with high aspirations who will succeed at Carnegie Mellon. If you’re applying to academic programs, your high school performance will be a significant factor in our admission decision because it’s the most meaningful indication of your motivation and abilities. We pay close attention to your curriculum rigor, the grades you’ve earned and the work you’ve accomplished. We’re interested in seeing that you’ve challenged yourself within your secondary school environment. If you’re applying to programs in the arts, your artistic performance will be either the main factor or a significant factor (depending on the program) in our admission decision.

Standardized test scores add to our knowledge of your preparation, but we don’t make decisions on the basis of test scores alone. Carnegie Mellon is test optional for fall 2025 undergraduate admission applications. However, students applying to the School of Computer Science are strongly encouraged to submit either an SAT or ACT score, including the math subscore, to bolster their application's strength and to aid in determining their ability to succeed academically at Carnegie Mellon. Pursuant to this policy, applicants aren't required to submit SAT or ACT results; however, results will be considered for those who submit them. Students who are unable to take either the SAT or ACT or choose not to submit their standardized test scores will be considered equally for admission along with those who submit scores. Please also note that submission of any prior SAT Subject Test results won’t be considered in our admission review process.

Your non-academic interests, including extracurricular involvement, part-time jobs, family commitments, hobbies and community engagement play a very important role in the admission process. We also consider collaboration, perseverance, passion, advocacy for others and self-direction when making admission decisions. We’re interested in students who can be successful at Carnegie Mellon while fully engaging in the university community. Because we want to have a sense of who you are as a person, we look closely at your Common Application essay, your short answer questions, your secondary school counselor's evaluation and your secondary school teacher's recommendation. By looking at this non-academic information, we develop a sense of your personality, motivation and responsibility.

We don't consider demonstrated interest in our admission process. Demonstrated interest is a term used in undergraduate admission that describes the ways in which a prospective student shows a college that they’re interested by visiting campus and submitting additional materials that aren’t required in the application. As a result, we don't consider a campus visit or communication with the Office of Admission or other members of the Carnegie Mellon community when making admission decisions.

Carnegie Mellon doesn't collect or review criminal history information as part of the admission process. However, individuals who are admitted to Carnegie Mellon will be required to disclose any past criminal conviction as part of the enrollment process. Learn how Carnegie Mellon considers criminal history (https://www.cmu.edu/hub/consumer-information/#criminaljustice) information.

COLLEGE CRITERIA

Each college/program at Carnegie Mellon has admission criteria specifically related to each course of study.

Admission to the Schools of Drama and Music is based primarily on a pre-screen, audition or (for select School of Music programs) portfolio review. Applicants to the Schools of Architecture, Art and Design will be evaluated not only on the basis of their portfolio review but also on their academic performance.

Applicants to the College of Engineering, Mellon College of Science, School of Computer Science and Tepper School of Business will be evaluated on their academic performance, with emphasis on strength in mathematics and science. Applicants to the Dietrich College of Humanities and Social Sciences and the Information Systems program will be evaluated on their academic performance, with emphasis on reading and comprehension abilities along with mathematics coursework. We'll also evaluate both groups of applicants based on their ability to communicate thoughts and ideas in writing.

Applicants should be aware of our admission requirements (https://www.cmu.edu/admission/admission/undergraduate-admission-requirements/) (secondary school preparation, nonacademic information and counselor and teacher recommendations) when submitting applications.

Think carefully about your Carnegie Mellon college selection(s) before applying. While you may apply to up to two colleges or programs that match your interests, bear in mind that most applicants will only be selected for their highest-choice college to which they‘re admissible. It’s rare for students, even of the highest quality, to be granted admission to more than one of their college selections. Early Decision and transfer candidates may only apply to their first-choice college or program at Carnegie Mellon. Please note that admission to the university is always contingent upon maintaining academic performance and community conduct commensurate with that which resulted in admission. Admission decisions will be rescinded for failure to maintain strong academic performance, community conduct, honesty, maturity and/or moral character.

Applying as a First-Year Student

If you're applying to Carnegie Mellon as a first-year undergraduate student entering in fall 2025, here's how to apply. Graduate students should refer to the Graduate and Postdoctoral Affairs website (https://www.cmu.edu/graduate/prospective/) for application instructions.

1. Choose your admission plan. Carnegie Mellon offers the following application plans: Regular Decision, Early Decision and Transfer Admission.

- **EARLY DECISION:** Early Decision is a binding application plan for students who view Carnegie Mellon as their first choice university. This means if you're admitted through Early Decision, you're committed to attending Carnegie Mellon and must withdraw any applications you may have submitted to other institutions. **Applications and supporting admission materials are due by November 1.** *Early Decision is not available for acting, directing, dramaturgy, music theater, BXA Design programs or the School of Music.*
- **REGULAR DECISION:** Regular Decision is the most common plan for students who apply to Carnegie Mellon. It’s common for students to apply Regular Decision to a number of institutions and then compare financial aid offers. **Applications and supporting admission materials are due by January 2.** Applications and supporting admission materials for **Regular Decision for the Schools of Drama and Music is December 1.**
- **TRANSFER ADMISSION:** Each year, Carnegie Mellon admits a small number of transfer students as space permits. The policy for transferring varies from college to college within Carnegie Mellon, so please carefully review the deadlines listed on the Undergraduate Admission website (https://www.cmu.edu/admission/admission/application-plans-deadlines/).

2. Complete the online Common Application (http://www.commonapp.org/). If you're applying for our Regular Decision plan, please request that your secondary school counselor submit all secondary school transcripts, including senior year courses and a school profile, to the Office of Admission as close to January 2 as possible, but no later than January 15. Mid-year grades should be submitted as soon as possible after they become available. It’s your responsibility to check what documents we’ve received on the Where Am I in the Process? portal to acknowledge receipt of these items. Receipt of mailed or faxed materials will be found on your Where Am I in the Process? portal within 7–10 business days after being received by the Office of Admission.

3. Apply for admission only to the specific college(s) or program(s) in which you're interested.

- Rank your program and/or major preference. We strongly urge applicants to indicate a program and/or departmental preference at the time they apply. Although students might not declare a major until the end of their first or second years, we have to limit access to certain departments.
- You may apply to up to two colleges/programs if your second choice program is from the College of Fine Arts—you cannot apply to more than one academic program. (Early Decision and transfer candidates may only apply to one college/program.)
- Students applying to CFA must apply directly to one or more of the following: School of Architecture, School of Art, School of Design, School of Drama or School of Music.
- If applying to more than one college, you must detail your multiple interests in the Carnegie Mellon short response questions.
- Be sure to review the admission requirements for each college/ program.

4. Send a non-refundable application fee of $75 electronically as you complete the Common Application. This fee is required. However, if you have a College Board or NACAC fee waiver or if you have any of the Common Application's listed economic indicators, you can note this on your registration form in order to have your payment waived. Only U.S. citizens, permanent residents and DACA students are eligible for fee waivers. An additional audition/portfolio review fee will be required at the time of online registration for Drama and Music pre-screening, audition or music portfolio review. For School of Music applicants, the additional audition fee is $55. For School of Drama applicants, the audition or prescreening fee is $120. These fees are payable at the time of reserving a pre-screening, audition or portfolio review online on the Fine Arts section of our website. For applicants to the Schools of Art, Architecture or Design, there is a $20 fee to submit the portfolio.

6. If you choose to have your SAT or ACT scores considered, you're required to submit all official results. While we're interested in the general pattern of your scores, we give the most weight to the highest score you've received on the SAT. On the ACT, we give most weight to the set of scores corresponding to the highest composite score. Carnegie Mellon does not super-score the ACT. We believe that college admission testing in the 9th and 10th grades adds to the anxiety of a process that students won't encounter for several years. As a result, we encourage students to submit 11th or 12th grade SAT or ACT scores (tests taken the summer after 10th grade are appropriate). While earlier tests may measure knowledge at the time they are taken, that level of knowledge gradually evolves and doesn't fully represent the knowledge students bring to college first-year courses. Should students present tests taken two or more years in advance of their first-year experience, we have to take the timing of the test result into consideration. The greater the amount of time prior to college matriculation, the less we can rely on the test result as a fair representation of a student's preparation entering first-year college courses.

7. If English is not your native language, submit additional test results. Applicants who don't speak English as a first language must submit the results of the Test of English as a Foreign Language (TOEFL), the International English Language Testing System (IELTS) or the Duolingo English Test.

8. If you're applying to the College of Fine Arts, submit your Common Application before completing portfolio submission, pre-screening or audition requirements. All of our fine arts programs require that students apply to the university and obtain their Application ID before registering for a pre-screening or audition, or before submitting a portfolio.

9. Sign the "FERPA Release Authorization" on the Common Application School Report Form and then request your secondary school counselor complete the form. Your counselor should submit this form to the Office of Admission along with the school profile and your transcript.

10. Choose a teacher to complete the Common Application Teacher Recommendation Form. Make sure it's submitted to the Office of Admission by November 1 for Early Decision and by January 15 for Regular Decision.

11. If you're applying for financial aid, submit all requested documents. We require financial aid applicants to complete the Free Application for Federal Student Aid (FAFSA) and the CSS Profile, and submit signed copies of parent/guardian and student tax documents. Learn more about applying for financial aid (https://www.cmu.edu/admission/costs-aid/) as an applicant.

Application Notification

- Students applying under the Early Decision plan will be notified of a decision by December 15.
- Students applying under the Regular Decision plan will be notified of a decision by April 1.
- Students who are applying for financial aid will also receive financial aid decisions by April 1 as long as they submit their financial aid forms by the preferred February 15 financial aid deadline.

If you're offered admission and wish to enroll at Carnegie Mellon, you're required to pay an $800 non-refundable enrollment deposit by May 1 (or February 15 for Early Decision admits) in order to reserve your place in the first-year class and in university housing. This deposit will be credited to your first semester's charges. The admission staff assumes that a student's deposit to Carnegie Mellon is their only deposit. We reserve the right to cancel our offer of admission if a student also posts a tuition deposit at another university. Throughout the summer, information concerning registration, enrollment, insurance, orientation, housing, dining, and more will be communicated to all incoming students.

Deferred Admission

If you're admitted to Carnegie Mellon and wish to defer your admission for one year, you must submit a written request to the Office of Admission. If permission is granted, your enrollment deposit must be paid to confirm enrollment for the following year. You must agree not to apply to or enroll in a full- or part-time degree program at another institution in the interim.

APPLICATION MISREPRESENTATION

We value academic and artistic integrity and authenticity in the admission process. Furthermore, Carnegie Mellon assumes that lists of activities, accomplishments, awards, essays and recommendations are authentic, original and accurately reflect student achievements. We reserve the right to launch an investigation when falsified transcripts, artistic submissions of work or misrepresentation of credentials that are not accurate, original and authentic representations of a student's ability and level of accomplishment are suspected. A student's admission status will be placed on hold during an investigation and can result in the cancelation of an application or the withdrawal of an offer of admission. Carnegie Mellon does report confirmed cases of misrepresentation to the Common Application.

All offers of admission are based on the assumption that students will maintain the level of academic performance and community conduct that has resulted in admission to Carnegie Mellon. Admitted and enrolled students are expected to abide by Carnegie Mellon's code of conduct, found within our student handbook, The Word.

Application Plans

Early Decision

These plans are ideal for students who view Carnegie Mellon as their first choice or if it has become their first choice before Regular Decision applications are due. For Early Decision, you'll apply by **November 1.** You'll apply to only one college within the university and receive your admission decision earlier (by December 15) in your senior year than our Regular Decision plan. If you're admitted under Early Decision, you've agreed to enroll, so this isn't the best plan if you want to compare financial aid offers from other institutions. *Early Decision is not available for acting, directing, dramaturgy, music theater, BXA Design programs or the School of Music.*

We give three admission decisions for students applying Early Decision: admit, not admit or, in some cases, defer to Regular Decision. Students who receive a "not admit" decision during Early Decision aren't eligible to apply for Regular Decision.

If you apply Early Decision, we encourage you to submit applications to other colleges/universities. However, you must agree to withdraw these applications if notified of Early Decision acceptance.

Applying Early Decision won't affect your overall admission decision. Students applying Early and Regular Decision are admitted at almost exactly the same rate.

Regular Decision

Regular Decision is our most popular application option. You'll apply to up to two colleges (if your second choice is from the College of Fine Arts) by

January 2 (December 1 for Drama and Music applicants). You'll be notified of your decision by April 1. Students admitted under Regular Decision will have until May 1 to accept our offer of admission.

Applying as a Transfer Student

Each year, Carnegie Mellon admits a very small number of transfer students where space permits. The policy for transferring into Carnegie Mellon varies from college to college. If you're interested in transferring into one of our academic programs, we must first make sure there's space available in your program of interest. Please note that space in these programs is extremely limited. If there's space, we'll look closely at your official college transcript, professor recommendations, high school grades and test scores (all SAT, ACT or language proficiency examination scores, if available). If you don't have official ACT or SAT results, there's no expectation to submit them.

In the College of Fine Arts, most transfer applicants are required to complete a pre-screen, audition or portfolio review.

Transfer Application Instructions

1. Apply for admission to the specific college or program in which you're interested. Make sure to note which department you prefer on the Common Application. Transfer students will only be considered for one college.

- Fall transfer is possible if space is available.
- Spring transfer may be possible for some colleges, but is extremely limited due to space constraints. CFA applicants cannot apply for spring admission.
- External transfers cannot apply to BXA programs.

Please submit your application by the deadline:

- Spring transfer: October 15
- Fall transfer: February 15 (December 1 for drama and music, January 3 for architecture, art and design)

Learn more about Transfer Application (https://www.cmu.edu/admission/admission/application-plans-deadlines/) deadlines.

2. Send a non-refundable application fee of $75 electronically as you complete the Common Application. This application fee is required, except in extenuating financial circumstances. To request a waiver, send us a letter from a college advisor or your dean requesting an application fee waiver in place of the application fee. Only U.S. citizens or permanent residents are eligible for fee waivers.

3. Send all college/university and secondary/high school transcripts to the Office of Admission. If you wish to attend Carnegie Mellon as a transfer student and have previously applied to the university, you must resubmit an updated Common Application with your application fee and all other required materials. *If you're admitted, make arrangements to have a final copy of your college transcript(s) sent to Carnegie Mellon.*

4. Send a copy of course descriptions from a college catalog from each college/university you attended so we can evaluate transferable credits. Course descriptions should be sent through the Common Application or by completing a form electronically (https://admission.cmu.edu/register/collegecourses/). You should copy and paste your course descriptions into a single document, saved as a PDF that has your name, address and Common Application ID on the first page. *If you're applying to Dietrich College of Humanities and Social Sciences for admission to select programs, you may also be asked to submit course syllabi.*

5. Sign the "FERPA Release Authorization" on the Common Application College Report Form. Have your dean or advisor at the college you're attending (or last attended) complete this form. Your dean or advisor should return the form directly to the Office of Admission.

6. Once available, check your Where Am I in the Process? portal for an official admission decision. If accepted, you'll need to complete an enrollment reply form. Please note that admission to the university is contingent upon maintaining academic performance and community conduct commensurate with that which resulted in admission. Admission decisions will be rescinded for failure to maintain strong academic performance, community conduct, honesty, maturity and moral character.

Deposit Information for Transfers

If you're offered admission for the spring semester, Carnegie Mellon does not require a tuition deposit due to the short time interval between December 15 and the start of the spring semester. If you're offered admission to the College of Fine Arts for the fall semester, you must pay a non-refundable deposit of $800 by May 1. If you are offered admission to Engineering, DC, IS, MCS, SCS, or Tepper for the fall semester, you must pay a non-refundable $800 deposit by June 1, even if you are receiving financial aid. The enrollment deposit will reserve your place at the university and a place in university housing if available. It will be credited to the first semester charges.

IMPORTANT: If you accept our offer of admission, we assume that your tuition deposit to Carnegie Mellon is your only tuition deposit. We reserve the right to cancel our offer of admission if you post a tuition deposit at more than one university. Enrollment deposits received after the deposit deadline will be returned if space is no longer available.

University Housing for Transfers

University housing isn't guaranteed for transfer students. Housing Services has a webpage available to help you locate housing accommodations (https://offcampus.housing.cmu.edu/) in the local area in the event that campus housing isn't available.

Transfer Credit Evaluated on Individual Basis

The college/school to which you're admitted will determine transfer credit for courses you've taken at other universities. We only offer transfer credit evaluations to admitted students. Transfer credit is considered on an individual basis. We may award elective credit for courses with no Carnegie Mellon equivalent.

Transfer credit for courses you're taking while we're reviewing your existing college record depends upon successful completion of each course. Grades aren't transferred — only credits. Sometimes transfer students have to take specific courses and accumulate a larger total number of credits than the normal amount required for graduation. The time it takes for you to graduate will depend on the time you need to complete the full university degree requirements — not on your class standing at a previous institution.

If you transfer in the fall semester, you'll be given instructions on how to receive an estimate of the additional academic work you must complete in order to fulfill the university degree requirements.

If you transfer in the spring semester, you'll have the opportunity to meet with an associate dean or advisor in order to outline the additional academic work you must complete to meet the university degree requirements.

It's best for transfer students in CFA to assume they'll receive first-year status. Occasionally advanced standing is awarded based on review of previous college courses.

You must make arrangements to have a final copy of your college transcript(s) forwarded to Carnegie Mellon's Office of Admission by July 1.

Applying as an International Student

International students should apply to Carnegie Mellon using the same procedures outlined for either first-year or transfer students. Also, note this additional information:

- Carnegie Mellon doesn't offer financial aid or installment plans to international students. International students aren't eligible for application fee waivers.
- If English isn't your native language, you're required to take the Test of English as a Foreign Language (TOEFL), the International English Language Testing System (IELTS), the Duolingo English Test, or the Cambridge English Assessment. Learn more about accepted scores (https://www.cmu.edu/admission/admission/international-applicants/#language).

Scores should be no more than two years old at the time of application, and we prefer that you submit all English proficiency test results from the past two years.

Regular Decision applicants should arrange to have these scores sent to Carnegie Mellon no later than January 7.

- InitialView (https://initialview.com/home/) or Vericant (https://vericant.cn/en/about-the-interview-en/) interviews are recommended for non-native English speakers but aren't required. Often these interviews can measure readiness for engagement in the classroom and also showcase a student's personality, likes and dislikes as well as the area of intended major. These interviews can also show English language proficiency while also corroborating the application with more details about the student.

Advanced Placement Consideration

Advanced Placement Program

Carnegie Mellon recognizes the Advanced Placement program and may grant advanced placement and credit for test scores of four or five (https://www.cmu.edu/hub/registrar/registration/ap-transfer-credit.html). When you take the tests, be sure you request that the results be sent to Carnegie Mellon.

INTERNATIONAL BACCALAUREATE PROGRAM

Carnegie Mellon also recognizes the International Baccalaureate Examination and may grant advanced standing and/or credit in various fields if scores on the higher level examination range from six and seven. (https://www.cmu.edu/hub/registrar/registration/ap-transfer-credit.html) Make sure you send these examination results to Carnegie Mellon.

College-Level Work

We may grant placement or credit for college work you've completed while in high school. Please have your college transcript(s) sent to Carnegie Mellon for transfer credit evaluation. Please send the descriptions of the college courses as well.

Cambridge General Certificate of Education

Carnegie Mellon recognizes the Cambridge GCE A-Level (advanced level) examinations in various higher-level subjects and may grant advanced placement and/or credit for exemplary grades (https://www.cmu.edu/hub/registrar/registration/ap-transfer-credit.html). Please note that we don't accept GCE "O" level examinations for placement.

College of Fine Arts Requirements

Detailed information may be found on the Office of Admission website (https://www.cmu.edu/admission/).

Deadlines

- Early Decision applicants must submit a complete admission application, including any required artistic evaluation, by November 1.
- Regular Decision applicants to Drama and Music must apply and make all pre-screen, audition or music portfolio review reservations by December 1.
- Regular Decision applicants to Art, Architecture and Design must apply by January 2 and submit their portfolio no later than January 15.
- We recommend that you apply for admission as early as possible in order to register for a pre-screen, audition or portfolio review, which are filled on a first-come, first-served basis.

Communicating Admission Decisions

- Final admission decisions aren't made at the time of your audition or portfolio review. We'll consider the artistic evaluation alongside the rest of your application and notify you of your admission decision by April 1 (by December 15 for Early Decision applicants).

BXA Intercollege Degree Programs

To be considered for the BXA programs (https://www.cmu.edu/admission/majors-programs/interdisciplinary-studies/bxa-intercollege-degree-programs/), you'll first select the College of Fine Arts school that you wish to apply to. You'll then be asked if you're interested in a BXA program and note your interest in either the Bachelor of Computer Science and Arts (BCSA), Bachelor of Engineering Studies and Arts (BESA), Bachelor of Humanities and Arts (BHA) or Bachelor of Science and Arts (BSA).

Note that BXA applicants are only reviewed for the College of Fine Arts (CFA.) If you indicate interest in the BXA program, you will not be reviewed for a second college/program outside of your CFA choice. The intercollege BXA offerings are designed for students who'd like to combine or juxtapose their interests in the arts and another academic program. Students must meet the admission standards of their academic choice and complete the specific application requirements for their CFA focus (portfolio review, pre-screen, audition or interview).

Indicating interest does not mean your offer of admission will include acceptance to one of our BXA programs. Notification of BXA admission will follow your initial offer.

BXA options aren't available for those applying to the School of Drama for Music Theater, or Acting, or for external transfer applicants. Under Early Decision, BXA is only available for the School of Drama options in Design/Production and the Schools of Architecture and Art.

Exploring Carnegie Mellon

A college visit is the best way to discover which school is right for you. We offer both in-person and online visit opportunities. Here are just a few ways to experience Carnegie Mellon from home, on campus and in your area. Learn more and register for visit opportunities (https://www.cmu.edu/admission/visit/).

CARNEGIE MELLON ON CAMPUS

Information Sessions

The Office of Admission offers on-campus information sessions (https://admission.cmu.edu/portal/campus_visit/) throughout the year. The session provides an experiential look at the university through student and faculty stories. You'll have the opportunity to learn more about Carnegie Mellon's areas of study, admission, financial aid and the city of Pittsburgh.

Campus Tour

During our campus tour, student "Tartan Ambassadors" will show you classrooms, laboratories, traditions and unique architecture around campus. They'll also answer your questions and share an insider's perspective on the Carnegie Mellon experience.

Outdoor Campus Walking Route

On this self-guided touring experience, you'll have the opportunity to walk an outdoor path around campus for one hour. Visit the Coulter Welcome Center (https://www.cmu.edu/visit/welcome-center.html) for details about a self-guided tour.

Admission Counseling Session

An Admission Counseling Session (https://admission.cmu.edu/portal/campus_visit/) allows you to meet one-on-one with an Admission Counselor to ask any questions you have regarding Carnegie Mellon, the opportunities on campus, or the application and admission process. These sessions are typically 20-30 minutes long.

Contact Carnegie Mellon for Assistance

If you need assistance while visiting campus, please contact us at admission@andrew.cmu.edu or 412.268.2082. We'll help meet your needs during your visit!

Carnegie Mellon Online

Virtual Campus Tours

When you can't make it to campus, we've got you covered. Our Tartan Ambassadors are hosting live Virtual Tours (https://admission.cmu.edu/portal/virtual_tours/) so you can experience Carnegie Mellon's campus from anywhere in the world. These Virtual Tours will offer you the opportunity to explore our campus while hearing more about the Carnegie Mellon experience.

Remote Information Sessions

Our remote Information Sessions (https://admission.cmu.edu/portal/remote_info_sessions/) are live events designed for you to learn more about the Carnegie Mellon experience. Led by our admission counselors, these hour-long webinars feature student stories, faculty highlights and detailed information about academics, student life and the admission and financial aid processes. You'll also have an opportunity to ask questions.

Remote Admission Counseling Session

We're currently offering remote admission counseling sessions (https://admission.cmu.edu/portal/adm_counseling_session_videocon/) for rising high school juniors and seniors. These virtual sessions allow students approaching the time of application to ask an admission counselor questions and seek guidance about Carnegie Mellon's unique colleges/programs and the admission process. Students and their families can join these sessions via video or phone call. Admission counseling sessions last about 20-30 minutes and allow time for parents or families to ask questions.

Tartan Talks

Tartan Talks (https://admission.cmu.edu/portal/Tartan_Talk/) are an online student panel series where interested visitors can learn more about the student experience at Carnegie Mellon University. Each Tartan Talk will feature our Tartan Ambassadors talking about their student involvement within academics, activities, research, the city of Pittsburgh and more. Bring your questions, and our Tartan Ambassadors will be ready to answer!

Carnegie Mellon in Your Area

Information Sessions Near You

We realize that it's not always possible for you to come to campus. The Admission staff does travel to different parts of the country and may offer information sessions in a city near you (https://www.cmu.edu/admission/visit/visit-opportunities-in-your-area/).

2024-2025 Cost of Attendance

The cost of attendance listed below references typical resident, commuter and off-campus undergraduate students. The academic year tuition charges are for full-time undergraduate students. A full-time student is one registered in a degree program and carrying a schedule of at least 36 units per semester. A student enrolled for less than 36 units per semester will be charged tuition on a per-unit basis. The university reserves the right to change its charges without notice. For full cost of attendance information, visit www.cmu.edu/sfs/tuition (https://www.cmu.edu/sfs/tuition/).

First-Years Entering Fall 2024

Per-Unit Tuition Rate - $898

CATEGORY	RESIDENT	COMMUTER
Tuition	64,596	**64,596**
Housing (1)	10,816	**0**
Food (2)	7,350	**3,674**
First-Year Experience Fee (7)	610	**610**
Technology Fee	470	**470**
Student Activities Fee	308	**308**
Transportation Fee	262	**262**
TOTAL TUITION, FEES & LIVING EXPENSES	**$84,412**	**$69,920**
Books, Course Materials, Supplies, Equipment (3)	1,000	**1,000**
Miscellaneous Personal Expenses (3)	1,300	**1,300**
Estimated Loan Fees (3), (6)	100	**100**
Transportation Allowance (3), (4)	0	**680**
TOTAL COST OF ATTENDANCE	$86,812	**$73,000**

Undergraduates Entering in 2023 & Earlier

CATEGORY	RESIDENT	COMMUTER	OFF-CAMPUS
Tuition	64,596	64,596	**64,596**
Housing (1), (5)	13,810	0	**9,316**
Food (2)	7,040	3,674	**7,040**
Technology Fee	470	470	**470**
Student Activities Fee	308	308	**308**
Transportation Fee	262	262	**262**
TOTAL TUITION, FEES & LIVING EXPENSES	**$86,486**	**$69,310**	**$81,992**
Books, Course Materials, Supplies, Equipment (3)	1,000	1,000	**1,000**
Miscellaneous Personal Expenses (3)	1,300	1,300	**1,300**
Estimated Loan Fees (3), (6)	100	100	**100**
Transportation Allowance (3), (4)	0	680	**680**
TOTAL COST OF ATTENDANCE	**$88,886**	**$72,390**	**$84,392**

Footnotes:

[1] All incoming first-year students are required to live on campus. Permission for first-year students to commute must be granted by Student Affairs. Off-campus housing allowance for returning students is $9,316.

[2] Food expenses for commuters is reduced based on a student's expected time on campus. For returning students, resident and off-campus food expenses is estimated using first-year resident food expenses minus $310.

[3] These expenses do not appear on the student account.

[4] Transportation allowance for resident and off-campus students varies based on home state.

[5] Housing for returning students is based on an apartment double rate, which is the most commonly available room for these students.

[6] Students who borrow federal loans will incur loan origination fees of 1.057% for Federal Direct Subsidized and Unsubsidized Loans and 4.228% for Federal Parent PLUS Loans. These fees will be included in an individual student's cost of attendance for financial aid purposes, as applicable.

[7] The first-year experience fee is applicable for both incoming first-year undergraduates and incoming transfer students.

Health Insurance

In addition, health insurance coverage is required. If a student is covered under a family's health plan, a waiver may be submitted to University Health Services for approval. View more details and estimated costs at www.cmu.edu/health-services/student-insurance (http://www.cmu.edu/health-services/student-insurance/).

Office of Enrollment Management

Dr. Kristina Wong Davis, Vice Provost for Enrollment Management & Dean of Admission
www.cmu.edu/hub (http://www.cmu.edu/hub/)

The Office of the Vice Provost for Enrollment Management and Dean of Admission provides vision and leadership for all aspects of Carnegie Mellon’s enrollment process. From the point of recruitment, the office is committed to fostering an environment where students and families feel welcome, prepared and supported during their transition to life at CMU all the way through Commencement. The office supports student success and positive outcomes by fostering collaborative partnerships across the university, promoting data driven decision-making, and planning for long-term enrollment strategy.

Enrollment Management is comprised of five functional areas and a one-stop student service center, which provide student-focused and highly efficient services and programs to support and enhance CMU’s recruitment and retention goals. The Office of Admission (p. 8), The HUB (p. 14), University Registrar’s Office (p. 15), Student Financial Services (p. 14), Office of International Education (p. 16), and Enrollment Systems work together to serve students, families and the campus community through strategic enrollment planning and delivering valuable and effective student support and administrative services.

The HUB

Keith Gehres, *Associate Vice Provost for Enrollment Innovation & Student Experience*
Melissa Skasik, *Director of The HUB*
Location: Warner Hall A12, 5000 Forbes Avenue, Pittsburgh, PA 15213
Phone: 412-268-8186
Fax: 412-268-8084
thehub@andrew.cmu.edu
www.cmu.edu/hub (https://www.cmu.edu/hub/)

The HUB Student Service Center

The HUB staff delivers comprehensive service and counsel to students and families regarding financial aid, billing and payment, registration, academic records, and ID Card services. In direct support of student enrollment and persistence, The HUB offers students and families highly integrated information through personal attention and technologically responsive tools in a professional, forward-thinking, and accessible environment.

Professional staff in The HUB serve as liaisons for specific colleges and support enrolled students with key aspects of the enrollment process – financial aid, billing and registration. Contact information for assigned HUB liaisons can be found on The HUB website (https://www.cmu.edu/hub/contact/) or the student's personalized Student Information Online (SIO) account.

Regular office hours for The HUB are: Monday and Wednesday (9 a.m. to 4:30 p.m.), Tuesday and Thursday (10:30 a.m. to 4:30 p.m.), and Friday (9 a.m. to 3 p.m.). These hours are subject to change, so visitors are asked to check The HUB's website (https://www.cmu.edu/hub/contact/) for the most up-to-date hours.

ID Card Services in The HUB

One of the most important items students will need at Carnegie Mellon is their official identification card. The CMU ID Card, administered through The HUB, classifies you as a member of the Carnegie Mellon community and is a part of everyday campus life. From bus access and Plaid Cash to campus events and museum entry, the ID Card is an essential tool for on and off campus.

View more information at www.cmu.edu/idplus (http://www.cmu.edu/idplus/).

Student Financials & Enrollment Systems

Brian Hill, *Associate Vice Provost for Student Financials & Enrollment Systems*
Location: Warner Hall A19, 5000 Forbes Avenue, Pittsburgh, PA 15213
Phone: 412-268-8186
Fax: 412-268-6651
thehub@andrew.cmu.edu
www.cmu.edu/sfs (https://www.cmu.edu/sfs/)

Student Financial Aid Office

Matthew Metz, *Director of Student Financial Aid*
Location: Warner Hall, 5000 Forbes Avenue, Pittsburgh, PA 15213
Phone: 412-268-8186
Fax: 412-268-6651
www.cmu.edu/sfs/financial-aid (https://www.cmu.edu/sfs/financial-aid/)

In alignment with the university's enrollment goals, Student Financial Aid consistently optimizes the utilization of all financial aid resources in order to recruit and retain a high quality and diverse student population. Student Financial Aid strives to deliver superior services that exceed the expectations of students, parents, and internal and external constituencies. Student Financial Aid identifies, creates and delivers strategies that facilitate the integration of financial aid policies. These policies align with current and future university recruitment, retention and enrollment priorities.

How Aid Works

Our financial aid program is need-based, meaning that all aid eligibility is determined by a student's family's financial circumstances. While student's and families have the primary responsibility for paying for college, financial aid can bridge the gap between the total costs and ability to pay.

Nearly half of our undergraduate students rely on some type of financial aid to pay for educational expenses. While many of our graduate students are offered departmental scholarships, grants, stipends, assistantships and fellowships, some rely on other resources, like federal loans, available through the Student Financial Aid Office.

Student financial aid offers may be comprised of scholarships and grants, student employment, and loans. In addition, options like the monthly payment plan may be suggested as a way to help budget payments of educational expenses and to limit debt. Like any major investment, most families pay for education with a mix of current income, savings and borrowing. Finding the right balance among these resources can save money.

For more information or complete steps for applying for financial aid at CMU, visit www.cmu.edu/sfs/financial-aid (https://www.cmu.edu/sfs/financial-aid/).

Types of Financial Aid

There are several types of financial aid available to students, such as federal and private loans, university scholarships, outside scholarships, federal and state grants, and student employment. A full listing and explanation of these types of aid may be found at www.cmu.edu/sfs/financial-aid/types (https://www.cmu.edu/sfs/financial-aid/types/).

Student Financial Aid Terms and Conditions

All students, regardless of whether they are financial aid recipients, are required to confirm agreement to the university’s student financial aid terms and conditions upon their initial log-in to Student Information Online (SIO) and before any financial aid disburses to their account. The terms and conditions apply to all student financial aid, regardless of source (e.g., federal, state or institutional), including grants, scholarships, fellowships, loans and work-study awards.

Learn more at www.cmu.edu/sfs/financial-aid/terms.html (https://www.cmu.edu/sfs/financial-aid/terms.html).

International Undergraduate Students

Only U.S. Citizens or Eligible Non-citizens are eligible to receive federal student aid. U.S. Citizens who were not born in the United States will need to send documentation of citizenship (i.e., a copy of passport or naturalization certificate). Verification is required for Eligible Non-citizens or refugees. Acceptable forms of verification include a photocopy of both sides of the student's I-551 or I-551C card.

Undergraduate international students are not eligible to receive federal or state student financial aid. Additionally, Carnegie Mellon does not award any institutional financial aid funds to undergraduate international students.

Student Accounts Office

Kurt Steinmiller, *Director of Student Accounts*
Location: Warner Hall, 5000 Forbes Avenue, Pittsburgh, PA 15213
Phone: 412-268-8186
Fax: 412-268-6651
www.cmu.edu/sfs/billing (https://www.cmu.edu/sfs/billing/)

The Student Accounts Office serves the university's various academic and administrative departments by processing and invoicing all student-related financial activity and managing the corresponding student financial obligations resulting from this activity. The office strives to serve students by accurately reflecting and communicating these financial obligations, providing timely and consistent responses to inquiries, and instilling financial responsibility and accountability with clear and concise guidance.

Student Financial Obligation Terms

Carnegie Mellon University wishes to be transparent about the financial expectations of students to the university. All students must acknowledge their agreement to the financial obligation terms only one time during their career at the university before access to Student Information Online (SIO) can be granted.

The student financial obligation terms (https://www.cmu.edu/sfs/docs/sfo-terms.pdf) (pdf) detail the student's responsibility to remit payment for charges incurred at the university as well as repercussions of non-payment.

University Charges

All charges incurred at the university are reflected on your student account. Charges include tuition and fees and may include housing, dining, sorority or fraternity charges, health insurance, Plaid Cash, and other miscellaneous charges incurred. Miscellaneous charges may include, but are not limited to, music lessons, library fines, parking fines, or emergency loans.

Student Account Invoices

Student account invoices are produced on the last day of each month. Invoices detail all transactions processed in the month, as well as any charges due in the future. Students receive an email notification to their Andrew email account when an invoice is ready for viewing on Student Information Online (SIO) (https://www.cmu.edu/hub/sio/about.html). Payments for amounts due from a monthly invoice must be received by the 15th of the next calendar month. Any amounts not paid by the stated due date are subject to a 1.5% interest charge each month until the balance is paid in full.

Carnegie Mellon does not print and mail student account invoices.

Billing Authorizations & My Plaid Student

Students may authorize Carnegie Mellon to send a PDF copy of their invoice to another individual's (parent, spouse, etc.) email address. After completing the authorization process, designated recipients will receive an email with a PDF attachment of the invoice and any related billing messages.

Students can also invite a bill payer or other individual to use My Plaid Student (MPS) (https://www.cmu.edu/hub/MyPlaidStudent/), which gives authorized users access to a student's invoices and student account activity, as well as the ability to make payments to the student's account. Students may also authorize their users to request enrollment verifications, and view grades and course schedules, via MPS. .

View more information at www.cmu.edu/hub/parents-and-family (https://www.cmu.edu/hub/parents-and-family/).

Tuition Assessment

The tuition charged to each student will be automatically adjusted on the 10th regularly scheduled class day (refer to the specific date noted in the Official Academic Calendar (https://www.cmu.edu/hub/calendar/) as the “last day to add courses”) based upon each student's schedule at that time. The tuition charged will be increased whenever the number of units added justifies tuition charges greater than those paid by the student at the time of fee settlement. After that time, no tuition adjustments will be made, with the exception of second minis for that particular semester.

For additional information, view www.cmu.edu/sfs/tuition/adjustment (https://www.cmu.edu/sfs/tuition/adjustment/).

Payment Options

Carnegie Mellon University is pleased to offer a wide variety of payment options for students and families. A full listing of these, as well as more information on each type, is available at www.cmu.edu/sfs/billing/payments (https://www.cmu.edu/sfs/billing/payments/).

We recommend that students enroll in Online Banking by linking a U.S. bank account to their student account via SIO. This is the fastest, easiest, and most convenient way to make a payment to or receive a refund from the university. The university does not initiate a withdrawal from a student's bank account; funds are only withdrawn when a student schedules a payment through SIO.

Refunds

If a student account has a negative balance resulting from an overpayment, financial aid, or a reduction of charges, the Student Accounts Office will review the account and issue a refund.

All students are encouraged to authorize electronic deposit of their student account refunds directly into their U.S. checking or savings accounts. Taking advantage of this opportunity eliminates the need to stand in line at The HUB to pick up a refund check and makes the funds available to the student within two business days.

If electronic refunding is not selected, the refund will be generated as a paper check that must be picked up in The HUB. Students who are issued a paper check for a student account refund have six months to cash the check. If the check is not cashed within six months, it will be voided and credited back to the student account and applied to any outstanding charges.

View more details about refunds at www.cmu.edu/sfs/billing/refunds (https://www.cmu.edu/sfs/billing/refunds.html).

Enrollment Systems

Dan Kennedy, *Interim Director of Enrollment Systems*
Location: Cyert Hall, 5000 Forbes Avenue, Pittsburgh, PA 15213

Enrollment Systems is charged with orchestrating the evolution of the Student Services Suite (S3) and related systems. As system administrators, business analysts and web developers, our department supports Carnegie Mellon University's student information system applications. Additionally, the goal of Enrollment Systems is to provide IT support and interface between and among the various student-system linked owners/users and the central IT technicians.

View details about the Student Services Suite (S3) at www.cmu.edu/s (https://www.cmu.edu/sfs/billing/)3-project (https://www.cmu.edu/es/s3-project/).

University Registrar's Office

Keith Gehres, *Associate Vice Provost for Enrollment Innovation & Student Experience*
John Papinchak, *University Registrar*
Location: Warner Hall A19, 5000 Forbes Avenue, Pittsburgh, PA 15213
Fax: 412-268-6651
cmuregistrar@andrew.cmu.edu (university-registrars-office@andrew.cmu.edu)
www.cmu.edu/hub/registrar (https://www.cmu.edu/hub/registrar/)

The University Registrar's Office performs the essential roles of administering the collection and maintenance of student records, ensuring their accuracy and integrity, and enforcing academic policies while providing the best possible services. The University Registrar's Office aspires to provide exceptional, environmentally-conscious services, while anticipating and meeting growing customer requirements with innovative processes, training and self-service applications. The office strives to foster and promote an environment of professional development and appreciation.

The University Registrar's Office produces the Academic Calendar (https://www.cmu.edu/hub/calendar/).

Enrollment

Enrollment is the process whereby eligible students notify Enrollment Services that they will be attending the university by registering for courses and settling their student accounts. Enrollment must be completed before students may begin classes and before they may utilize university facilities.

Registration

Registration is the process of selecting courses for the upcoming semester and discussing those selections with an academic advisor. We strongly encourage students to meet with their academic advisor before finalizing selections and registering for courses. The University Registrar's Office manages the registration process and related activities for all CMU students. Our goal is that our online services make these processes easy and secure. The registration process may be completed in Student Information Online (SIO) (https://www.cmu.edu/hub/sio/about.html) in four easy steps. Students can use the 4 Easy Steps to Registration (https://www.cmu.edu/hub/registrar/registration/steps/) webpage to find step-by-step instructions for course registration at CMU, including a pre-registration checklist, how to plan and check course schedules, share with schedules with advisors, confirm registration start time, and register for courses.

For most entering first-year students, registration is accomplished during the summer, with the assistance of associate deans and department heads. Academic placement and elective choice information is collected through mailed questionnaires during June and July. Most first-years complete their schedules and enrollment information prior to the first day of classes.

Currently enrolled students select their courses for the upcoming semester during Registration Week, prior to the end of each semester. The Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/) is available online prior to Registration Week, listing available courses along with general enrollment information. The university reserves the right to make changes to hours, units or instructional staff when such changes seem necessary or advisable.

Students are not permitted to register for courses in which the prerequisites have not been satisfied. Exceptions to the rule may be granted only upon the recommendation of the teaching department concerned. Unless the prerequisites are satisfied or special approval is obtained when the student enters the course, no credit can be allowed for the course. Students are also discouraged from planning schedules in which course time conflicts exist. For exceptional circumstances, however, students may register for, or add, courses with time conflicts. Information about managing course time conflicts is available on the 4 Easy Steps to Registration (https://www.cmu.edu/hub/registrar/registration/steps/#plan) webpage.

SUMMER & Non-degree COURSEWORK

Summer semester offers a great opportunity to enroll in Carnegie Mellon’s innovative courses and programs in fine arts, business, engineering, technology, liberal arts, and more. Summer classes allow more flexibility to focus on studies outside the typical fast-paced campus environment and more interactive learning with smaller class sizes. Our visiting and non-degree program (https://www.cmu.edu/hub/registrar/registration/vnd/) also allows professionals and non-CMU students to expand their education, and to learn from award-winning faculty. Summer courses are offered via three sessions: Summer All, Summer One and Summer Two.

PCHE Cross-Registration

Cross-registration provides opportunities for enriched educational programs by permitting full-time paying undergraduate and graduate students to cross register for one course at a Pittsburgh Council on Higher Education (PCHE) Institution. Students who are paying full-time Carnegie Mellon tuition (per the requirements of their home college) are eligible. The PCHE course may not count towards full-time status. There is no additional tuition charge, except for special course or laboratory fees. Carnegie Mellon students do not acquire status at the Host Institution, but are given library and bookstore privileges. Credit and grades are transferred directly to the home institution. Cross-registration is not applicable during the Summer Session or during intersessions.

For more information, visit www.cmu.edu/hub/registrar/registration/cross (https://www.cmu.edu/hub/registrar/registration/cross/).

Faculty Course Evaluations (FCEs)

Students play an integral role in the academic life of the university when they participate in the evaluation of the faculty through the Faculty Course Evaluation process. FCE data is important in the evaluation of teaching and learning, as an important piece of the promotion and tenure process and as part of the process of course design and improvement. Student participation in the FCE process is critical to the university's commitment to quality teaching and academic excellence. Students are strongly encouraged to participate in the process with constructive feedback that is relevant to teaching and course content. More information on the Faculty Course Assessment process and results from previous years may be found at www.cmu.edu/hub/fce (https://www.cmu.edu/hub/fce/).

Office of International Education & Study Abroad

Linda Gentile, *Executive Director of the Office of International Education*
Chris Menand, *Director of Study Abroad*
Location: Cyert Hall, Suite 101, 5000 Forbes Ave., Pittsburgh, PA 15213
Phone: 412-268-5231
o (thehub@andrew.cmu.edu)ie@andrew.cmu.edu (oie@andrew.cmu.edu)
w (https://www.cmu.edu/hub/)ww.cmu.edu/oie (https://www.cmu.edu/oie/)

The Office of International Education (OIE) is committed to empowering and inspiring Carnegie Mellon University students, faculty, staff and visitors to achieve their personal and educational goals in a community that encourages and values diverse ideas, life experiences and international perspectives. Supporting the university's educational mission, OIE promotes, advocates and facilitates international and cross-cultural experiences, perspectives and initiatives. OIE is the primary contact for study abroad programs and non-immigrant matters for all students and scholars (foreign professors and researchers) who are not United States citizens or permanent residents.

Foreign Students & Scholars

OIE serves as the liaison to the university for all non-immigrant students and scholars. The foreign student and scholar advisors counsel on immigration/visa, academic, personal, social and acculturation matters. Additional services include workshops in partnership with other offices on cultural adjustment, international career planning and tax filing. OIE supports international student groups, partners and family members with resources and programming that assist with acclimating to the broader community.

Study Abroad

Over 600 Carnegie Mellon students, from all majors, study abroad annually. With careful planning, students may study abroad for a semester, academic year or during the summer in various countries around the world, including Carnegie Mellon’s campus in Doha, Qatar. A well planned study abroad program will allow a student to receive credit for study abroad and graduate on time. There are additional opportunities for short-term, non-credit study abroad experiences. Many students are able to use their Carnegie Mellon funding for study abroad. The study abroad staff assist students in all stages of the process of going abroad. The advisors promote study abroad, advise students, work with the academic departments and conduct information sessions, pre-departure orientations and welcome back workshops. For more detailed information about Carnegie Mellon's study abroad program, see the Undergraduate Options (http://coursecatalog.web.cmu.edu/aboutcmu/undergraduateoptions/#studyabroadtext) section of this catalog or visit www.cmu.edu/studyabroad (http://www.cmu.edu/studyabroad/).

David & Susan Coulter Welcome Center

Rebecca Choltco, *Executive Director of Strategic Communication for Enrollment Management & Interim Director of the Welcome Center*
Location: Tepper Quad, Lower Level, 4765 Forbes Avenue, Pittsburgh, PA 15213
www.cmu.edu/visit/welcome-center.html (https://www.cmu.edu/visit/welcome-center.html)

The Carnegie Mellon University Coulter Welcome Center is a unique destination point for campus visitors. The welcoming space draws people in to engage with students and to see firsthand how Carnegie Mellon's expertise, ambition and world-leading technologies across business, the sciences, the humanities and the arts all benefit humankind. Visitors may register in advance for an in-person campus tour (https://www.cmu.edu/admission/visit/on-campus-visit-opportunities/) led by our Tartan Ambassadors or check out additional virtual opportunities (https://www.cmu.edu/admission/visit/online-visit/) to learn more about CMU and Pittsburgh.

Student Affairs

Gina Casalegno, Vice President for Student Affairs & Dean of Students
Location: Warner Hall 321, 5000 Forbes Avenue, Pittsburgh, PA 15213
Phone: 412-268-2075
www.cmu.edu/student-affairs (http://www.cmu.edu/student-affairs/)

The Division of Student Affairs is available to support and foster student intellectual and personal growth and help students explore and experience the different aspects of college life. We care about you, your studies, your social growth, your well-being and your future and want to help you enjoy a great Carnegie Mellon experience.

Central to our success is a commitment to cultivating deep and meaningful one-to-one relationships with students. We build and sustain collaborative relationships throughout the university to best serve the needs of our student body. Programs, services, and efforts are dedicated to the development of an engaged community among students, faculty, staff and alumni where meaningful and authentic exchanges are valued. Division of Student Affairs staff help students navigate and reflect upon challenges and transitions, and we empower them to become architects of their own learning and development.

The Office of the Dean of Students provides central leadership of meta-curricular experience at Carnegie Mellon, including divisional strategic planning, coordination of student support and crisis intervention, and facilitation of divisional assessment.

Student Affairs is comprised of the following offices and departments, which offer services aimed at enhancing the CMU student experience.

Athletics, Physical Education & Recreation

Josh Centor, *Director & Associate Vice President*
Location: Highmark Center for Health, Wellness, & Athletics, 100 Tech St, Pittsburgh, PA 15213
Phone: 412-268-8054
www.athletics.cmu.edu (https://athletics.cmu.edu/landing/index/)

The Department of Athletics, Physical Education and Recreation has a transformative impact through diverse programs that inspire leadership, teamwork, wellness and resilience, and offers students, staff and faculty opportunity to develop intellect, ethics and character needed to lead meaningful lives while impacting society in profound ways.

Career & Professional Development Center

Kevin Monahan, *Director & Associate Dean of Student Affairs*
Location: West Wing, 2nd Floor, 5000 Forbes Ave, Pittsburgh, PA 15213
Phone: 412-268-2064
career@andrew.cmu.edu
www.cmu.edu/career (http://www.cmu.edu/career/)

The Career and Professional Development Center (CPDC) is Carnegie Mellon University’s centralized career services center providing a comprehensive range of services, programs and materials focusing on career exploration and decision making, professional development, experiential learning and employment assistance to meet today’s evolving workplace and student goals of finding satisfying work.

Students wishing to explore how majors and minors relate to career choice, as well as gain information about particular fields, will work with a career consultant to examine their skills, interests, and values and how they relate to various career fields. Career consultants also coach students in writing resumes and cover letters, networking, locating internship and job opportunities, preparing for interviews, and pursuing graduate school opportunities. Career consultants are assigned to each college and provide individualized support, general career programming, and college-specific workshops. In addition to the workshops presented by the staff, consultants coordinate an annual professional development series presented by prominent alumni and recruiters in various industries and fields.

Handshake

Several thousand summer internships and professional full-time job opportunities are made available to Carnegie Mellon students through Handshake, an online job listing resource. Students can access Handshake through the Center's homepage (https://www.cmu.edu/career/) and can also use the service to search for student employment and on-campus jobs. Handshake also provides information on the hundreds of employers that visit our campus each year. These organizations interview students for internships and professional employment, as well as hold informational sessions in the evenings that are open to the entire campus.

Center for Student Diversity & Inclusion

M. Shernell Smith, *Executive Director*
Location: Cohon University Center, Lower Level, 5000 Forbes Ave, Pittsburgh, PA 15213
Phone: 412-268-2150
C (ocsi@andrew.cmu.edu)SDI@andrew.cmu.edu (CSDI@andrew.cmu.edu)
www.cmu.edu/student-diversity (https://www.cmu.edu/student-diversity/)

The Center for Student Diversity and Inclusion actively cultivates a strong, diverse and inclusive community capable of living out these values and advancing research, creativity, learning and development that changes the world.

The Center offers resources to enhance an inclusive and transformative student experience in dimensions such as access, success, campus climate and intergroup dialogue. Additionally, the Center supports and connects historically underrepresented students and those who are first in their family to attend college in a setting where students’ differences and talents are appreciated and reinforced.

Civility Initiatives

Candace C. Okello, *Assistant Dean of Civility Initiatives*
Location: Office of the Dean, Warner Hall 326, Third Floor, 4910 Forbes Ave, Pittsburgh, PA 15213
Phone: 412-268-2075
www.cmu.edu/student-affairs/civility (https://www.cmu.edu/student-affairs/civility/)

The mission of Civility Initiatives is to strengthen community and interpersonal relationships at CMU. The work of civility supports the academic, diversity, and well-being goals of the university through skill-building for civil discourse, conflict transformation, and restorative practice.

Cohon University Center

Marcia Gerwig, *Director*
Location: Cohon University Center 103, 5000 Forbes Ave, Pittsburgh, PA 15213
Phone: 412-268-2107
infodesk@andrew.cmu.edu
www.cmu.edu/cohon-university-center (https://www.cmu.edu/cohon-university-center/)

Designed to support health, wellness, and community engagement, the Jared L. Cohon University Center offers conference space and meeting rooms, a studio theater, a state-of-the-art fitness center, gymnasium, swimming pool, multiple dining locations, and plenty of gathering and study space.

Community Health & Well-being

Maureen Dasey-Morales, *Associate Vice President*

Location: Highmark Center for Health, Wellness, & Athletics, 100 Tech St, Pittsburgh, PA 15213
www.cmu.edu/wellbeing/ (https://www.cmu.edu/wellbeing/)

Community Health and Well-Being at CMU encompasses the following departments and initiatives: Counseling & Psychological Services, Religious & Spiritual Life Initiatives, Student Support Resources, University Health Services, and Wellness & Meaning-Making Programs. The Community Health and Well-Being services are also supported by departments like Athletics & Recreation, the Center for Student Diversity & Inclusion, the Office of Student Leadership, Involvement, & Civic Engagement, the Student Academic Success Center and many more. During your time at CMU, Community Health and Well-being is here to support and help you discover what well-being means for you. We have a lot of people who care and a lot of resources to help. All of these people and resources are organized into the Community Health and Well-being website (https://www.cmu.edu/wellbeing/) — a space for you to explore the various components of well-being and the opportunity for you to make any or all of it a part of your well-being journey.

Office of Community Responsibility

Lenny Chan, *Director*
Location: Morewood Gardens, 1060 Morewood Ave, Pittsburgh, PA 15213
Phone: 412-268-2140
communityresponsibility@andrew.cmu.edu
www.cmu.edu/student-affairs/ocr (https://www.cmu.edu/student-affairs/ocr/)

The Office of Community Responsibility (OCR) is staffed by an experienced team of professionals dedicated to the growth and development of students both in and outside of the classroom. When faced with a challenging or complicated situation, the office can serve as a resource for students, staff, faculty, and family members looking for guidance. Our staff strives to be approachable, knowledgeable, and current with best practices in the field of student conduct and academic integrity. The heart of our work is rooted in the value and support of our campus community members. We welcome inquiries regarding educational programming, student support, and guidance with the university's student conduct and academic integrity processes.

Counseling & Psychological Services

Shane Chaplin, *Executive Director*
Location: Highmark Center for Health, Wellness, & Athletics, 100 Tech St, Pittsburgh, PA 15213
Phone: 412-268-2922
www.cmu.edu/counselin (http://www.cmu.edu/counseling/)g (https://www.cmu.edu/counseling/)

Counseling and Psychological Services (CaPS) addresses the mental health needs of the university community by providing treatment to students and collaborating with staff, faculty and family members. CaPS helps students improve their psychological health by facilitating insight and fostering deeper understanding of their personal struggles needed to make better choices for themselves. Services at CaPS are developmental in nature, aimed at supporting students in the moment and in their personal growth and maturation over time.

CaPS is attentive to issues of diversity and equality. We respect and value each person as a unique individual. We offer a safe and supportive space for students who identify as LGBTQIA+ to navigate the challenges of exploring and integrating their gender and sexual identities.

Confidential services for students include consultation, short-term individual psychotherapy, crisis support and psychiatric referral when appropriate. Our staff provides consultation and education for students, faculty, staff and family members to address concerns regarding the well-being of a student, and questions about our services or psychological treatment.

CaPS staff also provide training and education for students and staff in support roles (i.e., advisors, Resident Assistants, Orientation Counselors, etc.)

Dining Services

Joseph Beaman, *Director*
Location: Residence on Fifth, 4700 Fifth Ave, Second Floor, Pittsburgh, PA 15213
Phone: 412-268-3782
dining@andrew.cmu.edu
www.cmu.edu/dining (https://www.cmu.edu/dining/)

Carnegie Mellon Dining Services offers a diverse portfolio of dining destinations, enriches and nourishes lives, and enhances the CMU transformative experience for students. We provide a unique and diverse food service program that meets the nutritional, educational, multi-cultural and social needs of students and the university community and contributes to the meta-curricular experience.

Family Engagement

Lauren Moran, *Associate Dean for Family Engagement & First-Year Orientation*
Location: 1060 Morewood Gardens, Pittsburgh, PA 15213
Phone: 412-268-2142
parents (parents@andrew.cmu.edu)@andrew.cmu.edu (career@andrew.cmu.edu)
www.cmu.edu/parents (https://www.cmu.edu/parents/)

Family Engagement encourages students to develop independence and the life skills necessary to successfully navigate their personal affairs as young adults. We know that family plays an important role and are key partners in our students' success. We're here to share information about general campus resources, important events and developmental milestones in the student experience, so students have information to facilitate meaningful interactions during their Carnegie Mellon journey.

First-Year Orientation

Lauren Moran, *Associate Dean for Family Engagement & First-Year Orientation*
Location: 1060 Morewood Gardens, Pittsburgh, PA 15213
Phone: 412-268-2142
orientation@andrew.cmu.edu
www.cmu.edu/first-year-orientation (https://www.cmu.edu/first-year-orientation/)

Orientation & First-Year Programs is responsible for providing vision and leadership for a comprehensive approach to new student orientation and transition programs. The office provides programs, opportunities and services to help students and family members successfully transition to the Carnegie Mellon community.

The office is responsible for program, development, marketing and implementation of orientation and transition programs. Areas of concentration include new student orientation, family programming such as Family Weekend, freshman programming series, and special event planning.

Fraternity & Sorority Life

Lauren Moran, *Interim Director*
Location: 1060 Morewood Gardens, Pittsburgh, PA 15213
cmu-fsl@andrew.cmu.edu
www.cmu.edu/fsl (http://cmu.edu/fsl/)

Fraternity and Sorority Life (FSL) is a core part of the undergraduate experience for many CMU students. The university's fraternities and sororities are committed to academic achievement, service, social interaction, and the wellness of their members. While individually unique, each chapter and council embraces inclusivity and upholds high standards of excellence in all aspects of campus life.

Housing Services & Residential Education

Lisa Hartman, *Director of Housing Services*
Tera Monroe, *Associate Dean & Director of Residential Education*
Housing Location: Residence on Fifth, 4700 Fifth Ave, Second Floor, Pittsburgh, PA 15213

Residential Education Location: Morewood Gardens, Student Life Suite, 1060 Morewood Ave, Pittsburgh, PA 15213
Phone: 412-268-2139 (Housing), 412-268-2142 (Residential Education)
housing@andrew.cmu.edu, resed@andrew.cmu.edu
www.cmu.edu/housing (https://www.cmu.edu/housing/)

The residential experience at Carnegie Mellon embraces all aspects of a student's life. Together, Housing Services and the Office of Residential Education create a lived experience that supports, engages, and inspires students throughout their university experience. It's the place they call home, the place where they will learn more about themselves, their community, and the world around them. Within a 24/7 community of support, staff and residents build meaningful relationships that inspire exploration, growth, and learning.

Pre-College Programs

Beth Yazemboski, *Senior Director*
Location: Residence on Fifth, 5000 Forbes Ave, Pittsburgh, PA 15213
Phone: 412-268-5914
precollege@andrew.cmu.edu (pc-life@andrew.cmu.edu)
www.cmu.edu/pre-college (https://www.cmu.edu/pre-college/)

Our Pre-College Summer Programs for high school rising juniors and seniors will show you what life at Carnegie Mellon is about — from the classroom to what's happening on weekends. You'll meet people from all over the world, be inspired by our world-renowned faculty, take part in the excitement of campus and have the opportunity to explore the city of Pittsburgh.

Religious & Spiritual Life Initiatives

Jennifer McCurry, *Coordinator*
Location: Highmark Center for Health, Wellness, & Athletics, 100 Tech St, Pittsburgh, PA 15213
www.cmu.edu/wellbeing/resources/wellness-initiatives/religous-spiritual (https://www.cmu.edu/wellbeing/resources/wellness-initiatives/religious-spiritual/)

Religious & Spiritual Life Initiatives offers programs and initiatives that cross traditional religious boundaries in order to increase our students' knowledge of and appreciation for the full diversity of the world's religious and spiritual traditions. RSLI's mission is to support all students along the spectrum of religious and spiritual practice and exploration.

Office of Student Leadership, Involvement, & Civic Engagement

Elizabeth Vaughan, *Director & Associate Dean of Student Affairs*
Location: Cohon University Center, 5000 Forbes Ave, Pittsburgh, PA 15213

Phone: 412-268-8704
slice@andrew.cmu.edu
www.cmu.edu/student-affairs/slice (https://www.cmu.edu/student-affairs/slice/)

The Office of Student Leadership, Involvement, & Civic Engagement (SLICE) complements students' academic experiences by providing services and resources that engage students in creating campus culture through social, cultural, intellectual, spiritual, athletic, recreational, artistic, political, and service opportunities. Our staff is committed to delivering quality advising, resource materials, leadership development opportunities, and administrative support services to impact students' growth and development and enhance the success of each student organization.

Our office partners with students to create a vibrant culture of student life on the Carnegie Mellon campus. Our community is home to nearly 250 recognized student organizations that are supported by the Student Activities staff team. In addition to serving as individual advisors to many organizations and providing resources, support, and ad hoc advising to all student organizations, our office also coordinates a slate of opportunities to help Carnegie Mellon students get involved in campus life.

Student Support Resources

Bryan Koval, *Director*
Location: Warner Hall 321, 4910 Forbes Ave, Pittsburgh, PA 15213
Phone: 412-268-2075
www.cmu.edu/wellbeing/resources/student-support-resources (https://www.cmu.edu/wellbeing/resources/student-support-resources.html)

The Student Support Resources team offers an additional level of support and expertise for students who are navigating any of a wide range of life events. Student Support Resources staff members work in partnership with campus and community resources to provide coordination of care and support appropriate to each student's situation.

University Health Services

Christine Andrews, *Executive Director*
Location: Highmark Center for Health, Wellness, & Athletics, 100 Tech St, Pittsburgh, PA 15213
Phone: 412-268-2157
health@andrew.cmu.edu
www.cmu.edu/health-services (https://www.cmu.edu/health-services/)

University Health Services (UHS) is staffed by physicians, advanced practice clinicians, registered nurses, and professional staff who provide medical care, health promotion and insurance services. A list of current services and fees may be found on the University Health Services website (https://www.cmu.edu/health-services/services-and-fees/).

Students are seen by appointment only. Same-day appointments are available on a limited basis depending on availability. We always do our best to work with patients with acute illnesses and injuries. To increase the likelihood of being seen sooner please contact us as early as possible. Call us at 412-268-2157, option 2 to discuss your needs.

HEALTH INSURANCE

Health insurance is vital to ensuring access to care and predictable health care costs, as well as aiding students in the achievement of their personal and academic goals. That is why CMU requires students to have medical insurance that meets university requirements each academic year, either through enrolling in the CMU Student Health Insurance Plan (SHIP) or obtaining a SHIP waiver. Visit the UHS Student Medical Insurance web page (https://www.cmu.edu/health-services/student-insurance/) for more information about student insurance.

Wellness & Meaning-Making Programs

Angie Lusk, *Director*
Location: Highmark Center for Health, Wellness, & Athletics, 100 Tech St, Pittsburgh, PA 15213
Phone: 412-268-7117
alusk@andrew.cmu.edu
www.cmu.edu/wellbeing/resources/wellness-initiatives (https://www.cmu.edu/wellbeing/resources/wellness-initiatives/)

Wellness and Meaning-Making Programs support our students, faculty, and staff as we individually and collectively work towards healthy, fulfilling lives and co-creating an enriching, supportive environment that helps all members to thrive.

Undergraduate Options

This section of the catalog introduces some of the options that undergraduate students can choose from to supplement their degree program, advance their career objectives, or focus on an interest that may be unrelated to their major. From IDeATe, which offers minors and courses in areas that merge technology and creativity like Game Design, to Student Defined Majors, which is designed for students whose academic goals cannot be adequately served by curricula of existing majors or minors, learn more about the additional options offered to CMU's undergraduate students.

Additional Majors/Dual Degrees

Students interested in pursuing more than one area of study are encouraged to consider an additional major or dual degree. Students who complete an additional major will earn a single degree in two areas. Generally, it is possible to fulfill the requirements of both majors in four years by taking the course requirements of the second major in the elective spaces allowed by the first major.

Some majors are offered only as additional majors:

- Students in the College of Engineering may elect to double major in Biomedical Engineering (p.) or Engineering and Public Policy (p. 145), which are offered only as an additional major.
- Students from any college may pursue an additional major in Human-Computer Interaction (p.), Science, Technology and Public Policy (p. 146), or Robotics (p.).

Dual Degree programs allow students to earn two degrees. Students who are interested in an additional major or dual degree are encouraged to review the specific possibilities with the relevant academic advisor.

Accelerated Master's Programs

Qualified undergraduates may apply to one of several programs to earn their bachelor's and master's degrees in five years. For further details about these programs, please refer to the appropriate college or departmental sections.

College of Engineering

The five-year Integrated Master's/Bachelor's programs offered by the Departments of Electrical and Computer Engineering and Civil and Environmental Engineering offers students superior technical preparation for careers in industry. The Departments of Chemical Engineering and Mechanical Engineering also offer fifth-year Accelerated Master's programs. The Department of Materials Science and Engineering offers a cooperative Industrial Internship Option in which students alternate coursework with practical experience in industry. Admission is highly competitive and leads to a Master of Science degree.

Dietrich College of Humanities and Social Sciences

The Department of Philosophy offers two bachelor's/master's degree options: the Bachelor's in Logic and Computation and Master’s in Logic, Computation & Methodology degree as well as a Bachelor’s/Master’s degree in Philosophy. The Institute for Politics and Strategy offers an accelerated Master of Science degree in International Relations and Politics. The Master of Arts in Teaching English to Speakers of Other Languages (TOESL) is a fifth-year master's option for Modern Language students who are concentrating in English as a Second Language. Also, the Department of English offers an accelerated program for undergraduates to obtain a Master of Arts in Professional Writing.

Heinz College of Information Systems and Public Policy

Heinz College's Accelerated Master's program allows qualified undergraduate students to earn a prestigious Master of Science degree in Public Policy and Management. For students in the College of Fine Arts or the Bachelor of Humanities and Arts degree program who are interested in careers in arts management, the program leads to a Master of Arts Management degree.

Mellon College of Science

The Honors Programs in the Departments of Chemistry and Mathematics are demanding, accelerated programs that give highly qualified students the opportunity to earn their bachelor's and master's degrees in just four years. Admission is by invitation only.

Tepper School of Business

Students who are interested in business management may wish to consider the Tepper School of Business 3-2 program. Qualified undergraduate students may earn their Master of Business Administration in addition to their bachelor's degree.

Health Professions Program

Jason D'Antonio, PhD, *Director*
Location: Doherty Hall 1320
Phone: 412-268-8494

The Health Professions Program (http://www.cmu.edu/hpp/) (HPP) at Carnegie Mellon University is an advising resource for all university students and alumni who are interested in a career in the health professions. This program complements a student's curricular advising and is meant to help students explore their interests, prepare for graduate programs in the health professions, and facilitate their application process. Students can enroll in the program at any time during their academic career, but the importance of early planning is communicated to interested first-year students. Once enrolled, students meet regularly with the director to discuss course requirements, medical exposure opportunities, and other aspects of preparing to be a competitive candidate.

Students in the HPP span all colleges of the university and have many diverse career interests including medicine, dentistry, optometry, biomedical research, medical physics, biomedical engineering, public health, medical informatics, and health policy.

For students interested in medicine or dental medicine, regardless of a student's major, the basic course requirements outlined below must be completed prior to matriculation:

1. One year of Biology with one lab, plus Biochemistry.

This is typically fulfilled by the following Carnegie Mellon courses:

03-121	Modern Biology	9-10
or 03-151	Honors Modern Biology	
03-135	Structure and Function of the Human Body	9
or 42-202	Physiology	
or 03-220	Genetics	
or 03-320	Cell Biology	
03-124	Modern Biology Laboratory	9-12
or 03-343	Experimental Techniques in Molecular Biology	
or 03-206	Biomedical Engineering Laboratory	
or 02-261	Quantitative Cell and Molecular Biology Laboratory	
03-231	Honors Biochemistry	9
or 03-232	Biochemistry I	

2. One year of Inorganic Chemistry with one lab.

This is typically fulfilled by the following Carnegie Mellon courses:

09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-207	Techniques in Quantitative Analysis (non-Chem majors)	9
or 09-221	Laboratory I: Introduction to Chemical Analysis	

3. One year of Organic Chemistry with one lab.

This is typically fulfilled by the following Carnegie Mellon courses:

09-217	Organic Chemistry I	9-10
or 09-219	Modern Organic Chemistry	

09-218	Organic Chemistry II	9-10
or 09-220	Modern Organic Chemistry II	
09-208	Techniques for Organic Synthesis and Analysis (non-Chem majors)	9
or 09-222	Laboratory II: Organic Synthesis and Analysis	

4. One year of Physics with one lab.

This is typically fulfilled by the following Carnegie Mellon courses:

33-121	Physics I for Science Students	12
or 33-141	Physics I for Engineering Students	
33-122	Physics II for Biological Sciences & Chemistry Students	9
or 33-142	Physics II for Engineering and Physics Students	
33-100	Basic Experimental Physics	6-9
or 33-104	Experimental Physics	

5. One year of Math.

21-111	Calculus I	10
21-112	Calculus II	10
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	
or 36-200	Reasoning with Data	
or 36-202	Methods for Statistics & Data Science	

6. One year of English.

This is typically fulfilled by the following Carnegie Mellon courses:

76-101	Interpretation and Argument (or any two of 76-106/7/8)	9
76-xxx	English course of the student's choice, typically 200-level or higher	

In addition to these general course requirements, recommended coursework includes statistics, behavioral sciences, ethics, and languages. Interdisciplinary studies are also strongly encouraged, and many students design an undergraduate curriculum that incorporates majors and/or minors in both the natural and social sciences.

Participating in research is a hallmark of the educational experience at Carnegie Mellon in many disciplines. Whether in the psychology lab studying the impact of breast cancer diagnosis on family social dynamics, in the NMR lab imaging metabolic function in the heart or brain, or in the surgery suite testing robotic devices, our students have made significant achievements in research. Health Professions programs are interested in applicants who have experience with the scientific method and who are intellectually curious about biomedical science, social science, biomedical engineering, as well as public health, epidemiology, and the social determinants of health.

Our university policy is to train students to be first class scientists, engineers, artists, writers, managers, or whatever their passion may be. We do not train students to be “pre-med,” but if they choose to use their talents in a health profession, we offer many services to help them obtain their life goals. Regular advising, application workshops, health issue seminars and symposium, community outreach activities, and preceptor-ship/ internship experiences are all part of our programming. The student pre-health organizations on campus: Doctors of Carnegie Society (DOCS); Student Diversity Inclusion Committee (SDIC); Alpha Epsilon Delta (AED); Global Medical Brigades; and Global Public Health Brigades, together with the HPP, provide students with opportunities to learn, explore, and prepare for their chosen area of professional interest.

The HPP has been successful in helping students to define, prepare for, and obtain their professional goals. Our students are regularly accepted at top-level medical, dental and graduate programs, and our alumni continue to serve as outstanding ambassadors of Carnegie Mellon.

IDeATe

The Integrative Design, Arts and Technology (IDeATe) (http://ideate.cmu.edu) network offers students the opportunity to become immersed in a collaborative community of faculty and peers who share expertise, experience, and passions at the intersection of arts and technology. Students will engage in active "learning by doing" in the IDeATe labs and classrooms based in Hunt Library. The program addresses current and emerging real-world challenges that require disciplinary expertise coupled with multidisciplinary perspectives and collaborative integrative approaches.

The IDeATe undergraduate curriculum consists of ten interrelated areas, all of which can be shaped into minors that students pursue alongside their primary majors. The themes of these areas integrate knowledge in technology and arts:

- **Game Design:** Design compelling game experiences and enhance your knowledge of key components of game design such as systems and mechanics, dramatic narrative and character development, programming and engine development, user testing and iterative development. Create games for a variety of audiences, including mobile applications, virtual reality platforms and even tabletop games.
- **Animation & Special Effects (p. 700):** Explore the technical and artistic aspects of 3D and 2D animation in an integrated manner and within different application contexts—from film animation and visual effects to interactive displays.
- **Media Design**: Design digitally mediated experiences across various platforms, from mobile devices to large-scale installations, and for varied applications—from media for daily living to mediated performances).
- **Design for Learning:** Explore the art and science of designing engaging learning experiences that creatively merge technology, learning sciences, and media arts know-how. Create inclusive learning media experiences ranging from mobile games to interactive museum exhibits, augmented classrooms, and adaptive ed-tech.
- **Sonic Arts:** Create experimental music and explore emerging applications and markets for sound design, music creation, and performance.
- **Innovation and Entrepreneurship:** Work collaboratively in hands-on explorations of the problems, opportunities, strategies, and circumstances that lead to innovations. You will experience integrated models of innovation that increase the likelihood of successful products and services that will bring value to society and/or the marketplace.
- **Intelligent Environments:** Design and implement interactive 3D spaces—both physical and virtual—that shape our experience of time and space.
- **Physical Computing:** Build interactive devices combining small programmable electronic controllers with physical embodiments, adding on-board processing and reactivity to nearly anything around you. Create novel games, useful devices, experimental provocations, and more.
- **Soft Technologies:** Weave together a rich set of traditions and experimental techniques to animate soft materials and matter.
- **Immersive Technologies in Arts & Culture:** Blend technological skills with creative imagination and critical humanistic practice.

Individuals who make significant contributions, academically and professionally, in these areas are solidly prepared in a related discipline. Their preparation is combined with the ability to work in multidisciplinary teams that span technology and the arts. IDeATe serves as a multidisciplinary collaborative learning addition to the education (and learning outcomes) that students receive through their disciplinary major rather than a standalone learning experience.

Innovation and advancement in the IDeATe areas, as in many complex areas of inquiry, is the result of collective inquiry and requires deep expertise in all contributing areas of knowledge (i.e., expert technologists and artists). Carnegie Mellon is the only university in the United States with highly ranked departments in key technological and artistic domains. With these resources, Carnegie Mellon is uniquely positioned to create faculty and student teams that contain all necessary, high-level expertise in tech-arts areas of inquiry.

Students who participate in IDeATe will be able to combine the unique experience of a "deep dive" in their chosen discipline while connecting to the diverse areas of knowledge and skill across the university. To help facilitate this experience, the educational objectives of the IDeATe network are:

- Students from any undergraduate major can integrate a tech-arts area of study into their curricular plan through the IDeATe minors, which enhance and synthesize the tech-arts ecosystem at CMU.
- Students in IDeATe have the opportunity to:
    - Immerse themselves in a collaborative community of faculty and peers who share expertise, experience, and passions at the intersection of arts and technology
    - Engage in active "learning by doing" in shared labs and maker spaces
    - Address current and emerging real-world challenges that require disciplinary expertise coupled with multidisciplinary perspectives and integrative approaches.

Across the ten IDeATe areas, there are over 50 multi-disciplinary technology-arts courses that a student can choose from to customize their paths. Students are assisted in their choice of courses and minor by a dedicated IDeATe advisor who works in tandem with the advisor in their home department.

The IDeATe Portal Courses introduce students to the concepts and practices of knowledge areas beyond their discipline that contribute to the subject of each minor/concentration. After completing the portal courses, students should be able to (1) interpret cross-disciplinary communication from their collaborators (and use that interpretation productively in the collaborative work), (2) translate their own disciplinary expertise to describe ideas and outcomes in a way their cross-disciplinary collaborators can understand, and (3) develop interdisciplinary tech-arts prototypes (that include perspectives from multiple disciplines and enable further interdisciplinary communication and collaboration).

The remaining courses of IDeATe deepen exploration in a given area. Each course is focused on a key aspect of the area that it is categorized under. By taking these courses, the student can become familiar with many of the technical and creative issues in the area of the minor and the collaborative processes they entail. These courses are collaborative because they promote hands-on learning through making, critique, and iterative design and they promote learning from both the instructor and the interdisciplinary peer cohort. At the conclusion of each course a student should be in a position to collaboratively plan and implement an established outcome in the area within a limited amount of time and apply skills from both technology and arts disciplines to prototype ideas and leverage the diversity of perspectives to produce innovation in the field.

A completion of a minor should provide multidisciplinary training in the area of the concentration and furthermore *enhance collaborative learning experience and skills of students*: diversify the cohorts of the student, enhance collaboration skills, promote cognitive versatility, facilitate skill transfer across technology and the arts, and produce graduates that can innovate in 21st century creative industries.

For more information, please visit the IDeATe website (https://ideate.cmu.edu).

Minors

In addition to a student's primary degree, they can choose a minor that is a secondary focus to the student's area of study, which can enhance a student's breadth of study and overall experience while not requiring the same amount of coursework as a second major or degree. The following list shows available minors. Unless otherwise indicated, minors are generally open to all university undergraduate students.

Intercollege:

- Game Design (IDeATe) (p. 887)
- Health Care Policy and Management (p. 889) (jointly between the Dietrich College of Humanities and Social Sciences, the H. John Heinz III College, and Mellon College of Science)
- Immersive Technologies in Arts & Culture (p.) (IDeATE and Department of Languages, Cultures, and Applied Linguistics)
- Music Technology (p. 329) (jointly between the School of Music and School of Computer Science)
- Neural Computation (p. 705) (jointly between the School of Computer Science, Mellon College of Science, and Dietrich College of Humanities and Social Sciences)

College of Engineering:

The following engineering minors are open to all Carnegie Mellon students:

- Biomedical Engineering (p. 192)
- Engineering Studies (p. 192)
- Technology and Policy (p. 192)

Designated Minors (open only to engineering students):

- Additive Manufacturing (p. 195)
- Audio Engineering (p. 196)
- Automation and Controls (p.)
- Colloids, Polymers and Surfaces (p. 197)
- Electronic Materials (p. 197)
- Global Engineering (p. 198)
- Materials Science and Engineering (p. 199)
- Mechanical Behavior of Materials (p. 199)

College of Fine Arts:

- Architectural Design Fabrication (p. 209) (available only to B. Arch candidates)
- Architectural Representation and Visualization (p. 209) (available also to B. Arch candidates)
- Architectural Technology (p. 209)
- Architecture (p. 209)
- Architecture History (p. 209) (available also to B. Arch candidates)
- Art (p. 211)
- Building Science (p. 209) (available only to B. Arch candidates)
- Collaborative Piano (p.) (available only to Piano majors in the School of Music)
- Conducting (p. 329) (available only to students in the School of Music)
- Design (p. 212)
- Drama (p. 213)
- History of the Arts (p. 211)
- Media Design (p. 211) (IDeATe)
- Music (p. 213)
- Music Education (p. 329) (available only to students in the School of Music)
- Music Technology (p. 329)
- Music Theory (p. 329)
- Musicology (p. 213)
- Photography (p. 215)
- Sonic Arts (p. 213) (IDeATe)
- Sound Design (p. 329) (IDeATe)

Dietrich College of Humanities and Social Sciences:

- African and African American Studies (p. 540)
- Anthropology (p. 419)
- Arabic Studies (p.)
- Behavioral Economics, Policy and Organizations (p. 497)
- Chinese Studies (p.)
- Cognitive Neuroscience (p. 478)
- Creative Writing (p. 375)
- Cybersecurity and International Conflict (p.)
- Decision Science (p. 498)
- English (p. 375)
- Ethics (p. 457)
- Film and Media Studies (p. 540)
- French and Francophone Studies (p.)
- Gender Studies (p. 541)
- German Studies (p.)
- Hispanic Studies (p.)
- Humanities Analytics (p. 375)
- International Relations and Politics (p.)
- Japanese Studies (p.)
- Linguistics (p. 542)
- Literature & Culture (p. 375)
- Logic and Computation (p. 457)
- Military Strategy and International Relations (p.)
- Philosophy (p. 457)
- Policy and Management (p. 499)
- Politics and Public Policy (p.)
- Professional Writing (p. 375)
- Psychology (p. 478)
- Rationality, Uncertainty, and Choice: Formal Methods (p. 457)
- Religious Studies (p. 544)
- Russian Studies (p.)
- Science, Technology and Society (p. 545)
- Social & Political History (p. 419)
- Societal & Human Impacts of Future Technologies (SHIFT) (p. 457)
- Sociology (p. 546)
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- Technical Writing (p. 375)

Mellon College of Science:

- Biological Sciences (p. 572)
- Chemistry (p. 600)
- Computational Finance (http://coursecatalog.web.cmu.edu/servicesandoptions/intercollegeprograms/#majorminorincomputationalfinancetext)
- Discrete Mathematics and Logic (p. 627)
- Environmental and Sustainability Studies (p. 660)
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- Scientific Computing (p. 660)

School of Computer Science:

- Animation & Special Effects (p. 700) (IDeATe)
- Artificial Intelligence (p. 677)
- Computational Biology (p. 681)
- Computer Science (p. 687)
- Design for Learning (IDeATe) (p. 700)
- Human-Computer Interaction (p.)
- Intelligent Environments (p. 700) (IDeATe)
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- Physical Computing (p. 700) (IDeATe)
- Robotics (p.)
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Tepper School of Business:

- Business Administration (p. 849)
- Business Analytics and Optimization (p.)
- Economics (p.)
- Innovation and Entrepreneurship (p.) (IDeATe)
- Financial Management (p.)
- Operations and Supply Chain Management (p.)
- Product Management (p.)

Pre-Law Advising Program

Director: Joseph Devine, *Associate Dean for Undergraduate Studies, Dietrich College*
Location: Dietrich College Dean's Office, Baker Hall 154
www.cmu.edu/pre-law (http://www.cmu.edu/pre-law/)

“Law School” is an objective that students frequently mention when asked about post-baccalaureate plans. It seems in its brevity to be a simple enough answer, but in reality it masks a host of complex and momentous personal decisions and strategic tasks.

First and foremost, seeking entry into law school implies an informed decision about the rigors of law school and the realities of professional life as an attorney, as well as a strong and mature commitment to achieving these objectives at significant cost and investment (financial, personal, and intellectual). Second, it implies an understanding of the prolonged sequence of steps involved in the process of selecting law schools to which to apply, actually applying, ultimately selecting a school to attend, financing a law school education, and succeeding in law school. Finally, it implies an understanding of this as one of many options that should be carefully considered before a choice is made that will so significantly influence the course of one’s personal and professional life.

To address these needs, the university offers a pre-law advising program for students and alumni who are contemplating or actively seeking to enter law school. The program consists of a range of support services, coordinated centrally, designed to assist these groups in engaging the complex questions associated with decisions about law school, and in successfully negotiating the sequence of tasks associated with selecting, applying and gaining admission to the best law schools possible.

The emphases of this program are:

- early identification of pre-law candidates;
- stimulation at early stages and throughout this process to consider the essential questions of personal suitability for law school and professional life as an attorney;
- engagement with meaningful substantive issues rooted in the law that illustrate the intellectual complexities of our legal system and the corresponding intellectual acumen needed to enter and thrive in this profession;
- timely direction in designing and executing a well-planned law school research, selection and application strategy;
- gathering and using accurate data on university alumni entering law school and the legal profession.

The program proper consists of several components, organized and made available as an ongoing service to all students and graduates of the university. These components include periodic workshops and seminars, a pre-law website, a pre-law newsletter, and linkage with law school admissions offices, the Law School Admissions Council, and associations (both regional and national) of pre-law advisors. The program also works closely with the student Pre-law Society.

Student Defined Majors

Carnegie Mellon offers the opportunity for undergraduate students to pursue a Student Defined Major. Some colleges have specific processes for Student Defined Majors within their college (see relevant college section of the catalog). For information and advice, interested students are encouraged to speak to the associate dean of their current home college or the college most relevant to the proposed course of study.

The requirements for successful completion of a Student Defined Major include a student proposal approved by an advisor, relevant college(s), the vice provost for education, and successful completion of the approved course of study. In brief:

- A student interested in pursuing a student-defined major must develop a proposal which outlines an intellectually coherent area of study (with degree title) and a plan of study (courses to be taken, pedagogical rationale, and proposed schedule). The proposal should include an explanation of why it is not appropriate or possible to pursue such a program through the curriculum of any one of the colleges. It should outline a program of study for both general education (for example, the core requirements of one of the most relevant colleges or equivalent general education plan) and major requirements. The proposal should designate one of the participating colleges as de facto “home college” for tracking and verification purposes.
- **Proposals must be approved at least one academic year prior to expected graduation.** Students should therefore submit their proposals by the end of their fifth semester, to allow ample time for approval.
- The student's proposal must be approved by a faculty advisor within a college who takes pedagogical responsibility for the program, by the de facto “home college” and by any other colleges involved in granting the degree. The signed proposal will be submitted to the Provost's Office for a final review and approval.
- Once approved by the faculty advisor, colleges, and the Provost's Office, the student's major will be administered by the advisor and their progress tracked by the dean's office of the “home college.” The “home college” will be responsible for monitoring the student's progress and reminding any collateral colleges of the approval of the Student Defined Major so that these colleges may insure the student's ability to enroll in the necessary courses. Upon successful completion of the course of study, the “home college” will be responsible for contacting all the relevant colleges and verifying the completion of the degree. Upon consultation with the “home college", students may receive their diploma in the most relevant department's ceremony.

Note: To distinguish Student Defined Majors from regularly offered majors at Carnegie Mellon, the phrase "(Student Defined Major)" will be added to the end of the major name. This notation will appear on all official documents (transcripts, verification letters, diplomas, etc.).

Student-Taught Courses (StuCo)

The Student College (StuCo) was established in 2001 to provide Carnegie Mellon students with the opportunity to share knowledge through educational, self-designed courses. Students can teach classes on any topic of their choice. However, the course cannot be available through regular university offerings. Courses typically meet once a week (for a full semester) and follow the current Carnegie Mellon academic calendar. Instructors and students receive credit (3 elective units - pass/no pass) for their work.

- All CMU students are eligible to teach StuCo courses and to join the Executive Committee that governs StuCo.

- All currently-enrolled CMU students, staff and community members are eligible to take StuCo courses.
- StuCo classes are taught during the fall and spring semesters.

StuCo courses vary semester to semester. Current classes offered by StuCo for fall 2023 include:

98-012	Student Taught Courses (StuCo): Fun with Robots	3
98-026	Student Taught Courses (StuCo): Genshin Impact: Team Building	3
98-038	Student Taught Courses (StuCo): Anime From Astro Boy to Your Name	3
98-043	Student Taught Courses (StuCo): Chess Tactics and Strategy	3
98-044	Student Taught Courses (StuCo): Introduction to Flag Design	3
98-057	Student Taught Courses (StuCo): Intro to Polytopes	3
98-061	Student Taught Courses (StuCo):UXplore: Uncover the Best of Modern UX Design	3
98-097	Student Taught Courses (StuCo): Intro to 3D Modeling- Character Design Pipeline	3
98-099	Student Taught Courses (StuCo): Problem Solving through Solving Problems	3
98-122	Student Taught Course (StuCo): Blackjack Techniques	3
98-123	Student Taught Courses (StuCo): Introduction to Hand Lettering	3
98-128	Student Taught Courses (StuCo): Fundamentals of Improv Comedy	3
98-148	Student Taught Courses (StuCo): Introduction to Student Journalism	3
98-154	Student Taught Courses (StuCo): Intro to Open-Source FPGA & ASIC Chip Design	3
98-156	Student Taught Course: Contemporary and Marginalized Poetics Workshop	3
98-157	Student Taught Courses (STUCO): Music: Deep-diving Artists and Genres	3
98-179	Student Taught Courses (StuCo): Introduction to Japanese Mahjong	3
98-203	Student Taught Courses (StuCo): Music and Interaction	3
98-205	Student Taught Courses (StuCo): Introduction to Minecraft	3
98-226	Student Taught Courses (StuCo): Movies You Should Have Watched By Now	3
98-230	Student Taught Courses (StuCo): Avatar: The Last Airbender & The Legend of Korra	3
98-242	Student Taught Courses (StuCo): Introduction to Esoteric Programming Languages	3
98-244	Student Taught Courses (StuCo): Sign Language Through Pop Music	3
98-258	Student Taught Courses (StuCo): Introduction to Competitive Pokemon	3
98-266	Student Taught Courses (StuCo): Private Pilot Ground School	3
98-272	Student Taught Courses (StuCo): Financial Literacy for Beginners	3
98-288	Student Taught Courses (StuCo): Star Wars: The Course Awakens	3
98-301	Student Taught Courses (StuCo): Taylor Swift Through the Eras	3
98-303	Student Taught Courses (StuCo): Introduction to Freestyle Rap	3
98-309	Student Taught Courses (StuCo): Build Your Own Startup	3
98-317	Student Taught Courses (StuCo): Hype for Types	3
98-335	Student Taught Courses (StuCo): Introduction to Glowstringing/Poi	3
98-341	Student Taught Courses (StuCo): Build Your Own Breadboard Computer	3
98-369	Student Taught Courses (StuCo): Brooklyn Nine-Nine	3
98-374	Student Taught Courses (StuCo): Steep by Steep: Investeagation into Tea Culture	3
98-375	Student Taught Courses (StuCo): Introduction to AI Alignment	3
98-390	They Came as Romans: Roman Civilization 360	3

For detailed information on the Student College, please visit the StuCo website (http://www.cmu.edu/stuco/).

Study Abroad Programs

Carnegie Mellon students from every major may be able to study in any part of the world for a semester, year or summer. Short-term programs during spring and winter break are also possible. A well planned study abroad program, in coordination with one's academic advisor, will allow a student to receive credit for study abroad and graduate on time. Most students study abroad during their junior year; however, a growing number of students are studying abroad during their sophomore and senior years.

The study abroad advising staff offers general information sessions as well as individual advising appointments to assist students in all stages of the study abroad process. The Office of International Education (OIE) also has useful web links to help students find the most appropriate study abroad program. In addition, OIE offers orientations to help with personal, academic and acculturation issues, before and after a study abroad experience.

Carnegie Mellon offers students a variety of payment options for study abroad to allow students to study abroad regardless of financial need. There are three categories of programs: Exchange Programs, Sponsored Programs, and External Programs. A description of each program follows.

More detailed information can be found at www.cmu.edu/studyabroad (http://www.cmu.edu/studyabroad/).

Exchange Programs

Students who participate in exchange programs pay Carnegie Mellon tuition and receive their regular financial aid package. Students are responsible for room, board, travel and miscellaneous expenses.

University Exchanges

Carnegie Mellon University has university-wide exchange programs with institutions located in Australia, Chile, Hong Kong, Israel, Japan, Mexico, Qatar, Singapore, and Switzerland.

Departmental Exchanges

Chemical Engineering, the College of Engineering, Design, Drama, Economics, Electrical and Computer Engineering, Heinz College, Computer Science and Business offer departmental exchange programs. Students should contact their department or the study abroad website for additional information.

Sponsored Programs

The university has designated a few study abroad programs administered by other organizations or universities as sponsored programs. To participate in these programs, students pay a university fee equivalent to current tuition, room and board, and retain their eligibility for all financial aid. Carnegie Mellon in turn pays the program costs to the study abroad program or institution. Where applicable, funds are distributed to the student for room, board, travel, and personal expenses.

Currently, Carnegie Mellon has approximately 50 sponsored programs available around the world. A full list can be found at www.cmu.edu/studyabroad (http://www.cmu.edu/studyabroad/) or in consultation with a study abroad advisor.

External Programs

Students may also participate in a program hosted by another university or study abroad organization if the student's home department approves the program and its course offerings. Students will pay the other organization or institution directly. Students who receive institutional aid from Carnegie Mellon will not be eligible for this aid while they are abroad. However, students with state and federal aid will still qualify. Students can learn more about external program options during study abroad advising appointments, information sessions, or on the study abroad website.

Undergraduate Academic Regulations

All enrolled students are required to comply with the university's Academic Regulations, as well as official University Policies (www.cmu.edu/policies (https://www.cmu.edu/policies/)). Students are expected to familiarize themselves with these regulations and are also advised to pay special attention to all academic dates and deadlines (www.cmu.edu/hub/calendar (https://www.cmu.edu/hub/calendar/)). The university reserves the right to change regulations and policies whenever such action is deemed appropriate or necessary.

Academic regulations are compiled by the University Registrar's Office. Students who have questions regarding these regulations should consult with their academic advisor.

Courses & Registration

Availability of Required Courses

In order to ensure that students do not have to compete for access to their required courses, registration priority is given to students who are registering for courses in their primary major. Although the university encourages the exploration of other disciplines, access to courses outside a student's primary major (including those courses that fulfill requirements for an additional major, minor, etc.) is on a space-available basis and is not guaranteed. Students must meet course pre- and co-requisites when registering, and are subject to course space availability. The university is committed to ensuring that each degree candidate has access to a normal course load before permitting other students to register for a greater than normal number of units.

Change in Schedule (Add/Drop)

Scheduling changes must be made within the period in the semester as established in the Official Academic Calendar (https://www.cmu.edu/hub/calendar/). A student **cannot drop a course** by simply notifying the instructor or by ceasing to attend class. A student dropping all of their courses (with the intent of leaving the university) must file an Application for Withdrawal or an Application for Leave of Absence (see the "Student Leave Policy" (p.) for more information).

Students are considered full time if registered for 36 or more units. Students should be sure to confirm their class level and enrollment status in SIO (https://s3.as.cmu.edu/sio/) prior to registering. Students must be registered for courses by the tenth day of classes or they will be administratively withdrawn for the semester. Any student who has been administratively withdrawn in error should immediately contact their academic advisor.

Students may drop a course by following the instructions for dropping a course in Student Information Online (SIO) on or before the appropriate deadline as published in the Official Academic Calendar. When a course is dropped by the drop deadline, the course is removed and does not appear on the academic record. Students may also use a late drop voucher for a limited number of course drops after the deadline during the pursuit of their degree. This action must be taken through consultation with their academic advisor or associate dean. Undergraduate students will receive three course drop vouchers throughout their undergraduate academic career and master's students will receive one voucher per 12 months of study. Only one drop voucher may be used per semester. In order to drop below 36 units, students must see their advisor for special permission. Vouchers are not intended to be used for exceptional or extenuating circumstances and they cannot be used to drop below full-time status (36 units). International students who wish to drop below full-time must consult the Office of International Education.

Students with a pending or documented academic integrity violation may not drop the course or change the course to P/NP, including the use of a voucher.

Undergraduate students who wish to withdraw from a course after the drop deadline must complete a Course Withdrawal form and **must** obtain their academic advisor's signature. The advisor will indicate whether they "recommend" or do "not recommend" withdrawal from the course on the form, sign the petition and submit it to the University Registrar's Office. When a course is withdrawn by the course withdrawal deadline, a "W" grade appears on the academic record.

The Late Add form is used for adding a course or switching sections after the add period and during the semester in which the course is offered. Students can check SIO to see if the appropriate schedule changes have been made. Undergraduate students who add a course or switch a section after the add period are required to obtain the permission of their advisor and home dean's office. Graduate students must have the permission of their department.

View details about course adds, drops and withdrawals on The HUB website (https://www.cmu.edu/hub/registrar/course-changes/).

Free Electives

A free elective is any Carnegie Mellon course that a student completes that is not being used to fulfill a college, school, major or minor requirement. A maximum of nine units of physical education and/or student-taught (StuCo) courses may be included in the tally of units required for graduation.

Overloads

The university is committed to insuring that each degree candidate has access to a normal course load before it permits other students to register for a greater than normal number of units. A normal course load has been established by each academic department. Students should check with their academic advisor or department for the definition of a normal course load. Individual colleges may have overload policies that are more restrictive, therefore students should consult with their advisor when considering an overload. Students may register for an overload up to 12 units with the approval of their academic advisor if they have demonstrated their ability to successfully complete a normal course load. Successful completion of a normal course load is defined as having earned at least a 3.00 (3.50 for students in ECE) cumulative QPA through the preceding semester or at least a 3.00 (3.50 for students in ECE) semester QPA in the current semester (in which case all final grades must be recorded before the student can register for the overloaded class). Overloads greater than 12 units or other exceptions must have the approval of the student's associate dean. First-year and transfer students are limited to a normal course load in their first semester of attendance.

Summer Classes

Per the Associate Deans' Council, undergraduate students are limited to registering for 24 units in summer sessions without advisor approval. If the student's advisor wishes to approve additional units after consulting with the student, the advisor can increase the student's course load units.

Conduct of Classes

Students are expected to attend all scheduled classes unless the instructor explicitly informs the class that other ways of doing the work are acceptable. The action to be taken in regard to tardiness, absence from class or making up late work is the responsibility of the individual instructor; the instructor should consult with the department head and the student's dean if major action, such as dropping the student from the course, is being considered.

All classes will be held at their scheduled hour on days immediately before and after all holidays and recesses. Both faculty and students are expected to be present.

Members of athletic teams and other student organizations are permitted to be absent from classes to participate in authorized contests and presentations, either at home or out of town, provided the following conditions are met:

- All work missed must be made up to the satisfaction of the instructor concerned;
- No trip shall involve an absence of more than two days, excluding days when classes are not scheduled;
- The total number of days of absence shall not exceed six per sport or per organization annually;
- Each student will obtain an absence authorization signed by the director or sponsor of the organization involved and by the Dean of Student

Affairs. The student will present this authorization to the instructor. This is not an excuse for work missed.

Technology affords many students access to mobile devices. It is expected that students will respect the wishes of faculty with regard to the use of electronic devices within the academic environment.

Students who, because of religious beliefs, cannot attend class may arrange as individuals to be absent, provided the work missed is made up in a manner satisfactory to the instructor of the class missed.

No student shall leave a scheduled exercise because of the absence of the instructor until a reasonable time has passed. By tradition and as a matter of courtesy a student should wait 10 minutes before leaving.

Course Attendance, STUDENT ACCOUNT BALANCE and Enrollment

A student is responsible for the payment of charges incurred at the university by the stated payment deadline. The purpose of this policy statement is to detail the specific process and action steps to be used to resolve any outstanding student account balance.

Students will be held financially and academically accountable for courses they attend or for which they are enrolled. Enrollment in a course which is not actively taken, or contrarily, the taking of a course for which enrollment has not been completed, will result in the assignment of a grade and responsibility for applicable tuition charges.

Students who fail to resolve their enrollment and balances will be prohibited from using university academic and administrative services. The services include, but are not limited to, computing facilities, library services, housing, dining, career center services, degree verification and the release of academic transcripts for the upcoming semester.

Undergraduate Course Meetings

Usually, no undergraduate classes, exams, academic, or artistic activities (including extra help sessions, rehearsals, ROTC drill, make-up exams, etc.) are scheduled on weekdays between 4:50 and 6:50 p.m. On occasion, some courses may be scheduled during these hours by the University Registrar's Office when they also are offered at other times; students may elect to take such courses during the 4:50 to 6:50 p.m. period.

Grades, Transfer Credit, Advanced Placement

Grading Policy

www.cmu.edu/policies/student-and-student-life/grading.html (https://www.cmu.edu/policies/student-and-student-life/grading.html)

This policy offers details concerning university grading principles for students taking courses, whether those students are undergraduates, non-degree students or graduate students. This policy covers the specifics of assigning and changing grades (including final and mid-semester grades, incompletes and conditional failures), grading options (audit and pass/fail), drop/withdrawals, and course repeats, as well as defines the undergraduate and graduate grading standards.

Questions about grading for a specific course should be addressed to the instructor of the course in question. Graduate students with questions about pass/fail and drop/withdrawal should contact their individual program. Appeals for an exception to any grading policy may be made by the dean's office of the student's home college.

Definitions

Certain terms are used in this document with specific meanings, as defined in this section.

Student means any full-time or part-time degree-seeking undergraduate or graduate student, or full-time or part-time non-degree student.

Non-degree student means a student who is not in a university degree program.

Faculty means members of the university's Faculty Organization as defined in the Faculty Handbook, plus instructors and special faculty appointments (even in their first year), and part-time faculty.

Instructor means a faculty member, teaching assistant, and /or lecturer who is the instructor of record, as recorded in the Student Information System (S3).

Policy Provisions

Assigning Grades

Final grades are awarded to each student, in each course scheduled, at the end of the semester, mini-semester or summer session. All students taking a course at Carnegie Mellon must be assigned grades.

The University Registrar's Office will query instructors who do not assign a grade to a student. Copies of the query regarding the lack of grade will be sent to the course's department head and associate dean. If the instructor does not assign a letter grade or an incomplete grade within one month of that query, the teaching department head will be responsible for insuring that a grade is assigned.

Changing a Grade

A student who believes that an assigned grade is incorrect may request that a final grade be changed. This action should be taken as soon as possible but no later than one year after the final course grade was issued. Final grades will be changed only in exceptional circumstances and only with the approval of the instructor and, for undergraduates, with the approval of the dean's office of the college/school offering the course; for graduate students, department approval is required. The intention of this policy is to ensure that, under normal circumstances, all students in a class are treated equally and no student is unduly advantaged.

Mid-Semester Grades

Mid-semester grades provide valuable feedback to students as they assess their performance in courses. Furthermore, mid-semester grades and the QPAs they generate are used by deans and advisors in identifying and dealing in a timely way with students in academic trouble. Therefore it is imperative that mid-semester grades accurately reflect student performance and are turned in on time.

Mid-semester grades are not permanent and are kept only until final grades are recorded. Because mid-semester grades are not permanent, changes of mid-semester grades as a rule will not be accepted.

Incomplete Grades

Carnegie Mellon students are expected to complete a course during the academic semester in which the course was taken. However, if the instructor agrees, a grade of I (incomplete) may be given when a student, for reasons beyond their control, has been unable to complete the work of a course, but the work completed to date is of passing quality and the grade of incomplete provides no undue advantage to that student over other students.

In awarding an I grade, an instructor must specify the requirements for completing the work and designate a default letter grade where no further work is submitted. Students must complete the required course work no later than the end of the following academic semester, or sooner if required by prior agreement. The instructor must record the permanent grade by the last day of the examination period of that following semester, or the University Registrar's Office will administratively assign the default grade.

Pass/No Pass Grades

Undergraduate students may elect to take a free-elective course pass/no-pass unless precluded by the course, the course's department or the student's home department/college. Policies for graduate students vary and students should be advised to check with their individual colleges/departments/programs for details.

A student must submit a Pass/No-Pass form to the University Registrar's Office indicating the course they are electing as pass/no-pass before the end of the university's withdrawal period. This decision is irreversible thereafter. No information regarding the student's decision will be passed on to the instructor. Instructors will submit letter grades, which will automatically be converted to pass/no-pass.

Work graded A through D will receive credit for units passed and be recorded as P on the student's academic record; below D work will receive no credit and will be recorded as N on the student's academic record. No quality points will be assigned to P or N units; P or N units will not be factored into the student's QPA.

In exceptional circumstances, departments may ask to designate a course pass/no-pass or request that the course be evaluated only with letter grades. The College Council must approve designating a course as pass/no-pass only or as graded only. If such a decision will have an adverse effect on the requirements of any other college, Academic Council must review the decision. The decision to designate a course as graded or pass/no-pass must be made before the add period for the course and is irreversible thereafter.

Audit Grades

Auditing is presence in the classroom without receiving academic credit, a pass/fail or a letter grade. The extent of a student's participation must be arranged and approved by the course instructor. A student wishing to audit a course is required to register for the course, complete the Course Audit Approval form, obtain permission of the course instructor and their advisor, and return the form to The HUB prior to the last day to add a course.

Any student enrolled full-time (36 units) may audit a course without additional charges. Part-time or non-degree students who choose to audit a course will be assessed tuition at the regular per-unit tuition rate.

Drop/Withdrawal Grades

Students at Carnegie Mellon may drop a course by accessing online registration in SIO on or before the drop deadline as published in the official university calendar. Policies for graduate students vary and students should be advised to check with their individual colleges/departments/programs for details. When a course is dropped by these deadlines, the course is removed and does not appear on the academic record.

Undergraduate students who wish to withdraw from a course after the drop deadline must complete a Course Withdrawal form and **must** obtain their academic advisor's signature. The advisor will indicate whether they "recommend" or do "not recommend" withdrawal from the course on the form, sign the petition, and assign the "W" (withdrawal) grade in S3. The "W" grade will appear on the academic record. Withdrawal grades do not apply to graduate students, except in CFA, DC and SCS. Students may use a late drop voucher for a limited number of course drops after the deadline during the pursuit of their degree. This action must be taken through consultation with their academic advisor or associate dean. Learn more about course drops, withdrawals and vouchers at www.cmu.edu/hub/registrar/course-changes (https://www.cmu.edu/hub/registrar/course-changes/).

Undergraduates who are registered as full-time students as of the 10th day of classes are expected to remain full-time for the duration of the semester. Full-time is defined as registered for a minimum of 36 units. Permission to drop below the 36-unit minimum can only be granted in extraordinary circumstances by the student's home associate dean. Undergraduates who are registered as part-time are also subject to the above deadlines to drop or withdraw from a course.

Course Repeats

When a course is repeated, all grades will be recorded on the official academic transcript and will be calculated in the student's QPA. This is the case regardless if the first grade for the course is a passing or failing grade, including pass/fail.

Undergraduate students who wish to repeat a course already passed must obtain approval from the student's dean or department head. When a student takes a course they have already passed, only one set of units will count toward graduation requirements.

University Grading Standards

The undergraduate student grading standard is as follows:

Grade	Quality Points	Definition
A	4.0	**Excellent**
B	3.0	**Good**
C	2.0	**Satisfactory**
D	1.0	**Passing**
R	0.0	**Failure**
P	Non-Factorable	**Passing**
N	Non-Factorable	**Not Passing**
O	Non-Factorable	**Audit**
W	Non-Factorable	**Withdrawal**
I	Non-Factorable	**Incomplete**
AD	Non-Factorable	**Credit granted for work completed at another institution or examination credit**

This grading standard is for all students classified as seeking an undergraduate degree and special students taking undergraduate courses.

Any +/- grades received by undergraduate students when taking graduate-level courses will automatically convert to the corresponding letter grade as listed in the scale above.

The graduate student grading standard is as follows:

Grade	Quality Points	Definition
A+	4.33	**(Not applicable to CIT or Dietrich College students)**
A	4.0	
A-	3.67	
B+	3.33	
B	3.00	
B-	2.67	
C+	2.33	
C	2.00	
C-	1.67	
D+	1.33	**(Not applicable to Tepper School, Heinz College, or Dietrich College students)**
D	1.00	**(Not applicable to Tepper School, Heinz College, or Dietrich College students)**
R	0.0	**Failure**
S	Non-Factorable	**Satisfactory**
P	Non-Factorable	**Passing**
N	Non-Factorable	**Not Passing**
O	Non-Factorable	**Audit**
W	Non-Factorable	**Withdrawal**
I	Non-Factorable	**Incomplete**
AD	Non-Factorable	**Credit granted for work completed at another institution or examination credit**

Grading standards are based upon a student's home academic program and is defined by their home college. The college's standards determine if certain grades are applicable and if undergraduate courses are factored into their mid-semester and final semester quality point averages (QPA). Otherwise, the university policy is that only graduate courses (600 level and higher) are factored into the semester QPA.

Pass/fail policies for graduate students vary and students should be advised to check with their individual college/department/program for details.

Minimum passing grades in graduate courses are determined by the department and college policy. Any course that a graduate student completes will be graded using the scale above. This includes undergraduate courses taken by graduate students, and non-degree students taking graduate courses.

Contact

Questions concerning this policy or its intent should be directed to the University Registrar's Office at 412-268-7404.

Units and Quality Points

Carnegie Mellon has adopted the method of assigning a number of “units” for each course to represent the quantity of work required of students. For the average student, one unit represents one work-hour of time per week throughout the semester. The number of units in each course is fixed by the faculty member in consultation with the college offering the course. Three units are the equivalent of one traditional semester credit hour.

Hence, a 9-unit semester-long course should require 9 hours of student engagement, on average, including class time; if the instructor requires 3 hours of lecture and 1 hour of recitation, they can expect students to spend 5 hours outside of class engaging in class work. For mini courses that run for only seven weeks, the conversion from units to number of hours per week during the mini involves multiplying by 2. For example, a 6 unit mini course should on average involve 12 hours of student engagement; if the instructor requires 3 hours of lecture and 3 hours of lab, they can expect the students to spend 6 hours outside of class.

Final grades are given “Quality Point Values” as follows:

Grade	Meaning	Quality Point Value
A	Excellent	**4**
B	Good	**3**
C	(Satisfactory)	**2**

D	Passing	**1**
R	Failure	**0**

Units earned for a course multiplied by the Quality Point Value of the grade given for that course equals the quality points for that course. For example, a 9-unit course assigned a “C” grade is awarded 18 quality points (9 units x 2 quality points = 18 quality points). Total Quality Points divided by Total Units Factorable equals the Quality Point Average.

For example, a student's record in one semester might be:

11 units x 4 quality points	=	**44 quality points**
10 units in Physics “R”		
10 units x 0 quality points	=	**0 quality points**
9 units in Chemistry “B”		
9 units x 3 quality points	=	**27 quality points**
9 units in History “C”		
9 units x 2 quality points	=	**18 quality points**
9 units in English “D”		
9 units x 1 quality point	=	**9 quality points**
Total Units = 48		
Total Quality Points = 98		
Quality Point Average (98 divided by 48) = 2.04		

“I” (incomplete), “P” (pass), and “W” (withdrawal) grades are not awarded quality points and are not considered “factorable” units when calculating the QPA.

The same procedure is applied to all grades earned at the university to establish the Cumulative Quality Point Average.

Dean's List

Undergraduate students who meet specific academic requirements are added to their home college's Dean's List each semester. This is noted on the student's transcript for applicable semesters. Each college may have its own requirements for Dean's List qualification; these are described in the individual college sections of the catalog. Note: Only undergraduate *degree-seeking* students may earn a place on the Dean's List. Non-degree students are not eligible.

Transfer Credit Evaluation and Assignment Policy

https://www.cmu.edu/policies/student-and-student-life/transfer-credit-evaluation-and-assignment.html

The Policy on Grades for Transfer Courses, originally dated January 13, 1993, and approved by the Committee on Educational Programs and Student and Faculty Affairs states:

Carnegie Mellon University offers students the opportunity to take courses for credit through a cross-registration program and through the receipt of transfer credit from other accredited institutions. The Carnegie Mellon University transcript will include information on such courses as follows:

Carnegie Mellon courses and courses taken through the university's cross-registration program will have grades recorded on the transcript and be factored into the QPA. All other courses will be recorded on this transcript indicating where the course was taken, but without grade. Such courses will not be taken into account for academic actions, honors or QPA calculations. Note: Suspended students may take courses elsewhere; however, they may receive transfer credit only if their college's and department's policies allow this.

Definitions

A Carnegie Mellon course is one conducted under Carnegie Mellon University regulations regarding course content and grading and taught by faculty under the supervision of a Carnegie Mellon academic unit. Courses taught by Carnegie Mellon faculty on the Carnegie Mellon campus qualify. Courses that are part of the regular offerings of other universities do not qualify, unless faculty at the other universities receive appointments at Carnegie Mellon and handle Carnegie Mellon students under Carnegie Mellon academic regulations.

Courses offered for cross-registration are those taken under the PCHE (Pittsburgh Council on Higher Education) agreement during the regular academic year.”

Only official and final college or university transcripts will be accepted for the awarding of transfer credit. Grade reports, letters and the like are not acceptable. It is the responsibility of the Office of Undergraduate Admission and the University Registrar's Office to verify official transcripts. Official transcripts for the awarding of transfer credit will reside in the student's permanent university academic folder in the University Registrar's Office.

It is the responsibility of each academic department to review and establish transfer course credit for their degree-seeking students.

Transfer Credit Evaluation Procedure

External Transfer Students

External applicants applying for transfer to Carnegie Mellon will arrange for submission of:

- official transcripts to the Office of Undergraduate Admission as part of the admission process.
- official, final transcripts to the Office of Undergraduate Admission once they are admitted and prior to their beginning coursework at Carnegie Mellon.

As part of the admission process, the Office of Undergraduate Admission will verify the official final transcripts, and then send them to the appropriate academic unit responsible for college/department acceptance decisions. Each unit will be responsible for the review of transfer credit and the establishment of transfer course credit for each individual student.

Current Students

Current Carnegie Mellon students taking courses at other accredited institutions (colleges and universities), during either summer semesters or as part of exchange programs or other departmentally approved programs, or while on leave from Carnegie Mellon, must arrange for the submission of official final transcripts to the University Registrar's Office.

Upon receipt, the University Registrar's Office will verify these official transcripts and send a copy of the transcript to the appropriate academic unit responsible for that student's college/department transfer credit decisions. The official transcript will reside in the student's university academic record in the University Registrar's Office. Each unit will be responsible for its students' transfer credit review and the establishment of transfer course credit for each individual student. Should a unit receive the official transcript, it must be sent immediately to the University Registrar's Office.

Administrative Procedures on Transfer Credit

To be considered for transfer credit, an approved course must be taken for an assessed grade and completed with a grade of C- or better (or equivalent of a U.S. C- grade). Ungraded or pass/fail courses may receive credit if the transcript key indicates that the mark represents a grade of C- or better. CMU does not discriminate against particular institutional settings or modes of delivery and strives for fairness and transparency as outlined in the Middle States Commission on Higher Education standards.

The coursework must be issued on an official transcript from a regionally accredited US college or university, or from an international institution of post-secondary education that carries globally recognized accreditation from the relevant Ministry of Education (or equivalent higher-education authority/appropriate government agency) and that offers university-level academic degree program courses comparable to a U.S. associate’s or bachelor’s degree. Transcripts from institutions outside the United States should be evaluated course-by-course by a NACES-approved credential evaluator and sent to CMU as part of the undergraduate admissions process.

Courses eligible for evaluation will be considered case-by-case to confirm equivalencies based on course content and academic rigor. Courses must include the same, or similar, content to CMU undergraduate courses; require the same, or similar, prerequisite coursework; and be offered at the same level of instruction. The student’s home major or minor department will determine how approved credit will apply to a student’s major or minor. Approved courses not given a direct equivalency may serve as general electives, units towards the degree, and breadth units where appropriate. A candidate for a bachelor's degree must complete at least 180 units of coursework at CMU.

CMU will not accept any math courses below Calculus 1. English-language courses, career preparation and first-year seminars, Algebra-based physics, and first-year writing are also not permitted to be transferred to CMU.

Standard Course Equivalents for Advanced Placement/International Baccalaureate Units Policy

The university has standard units assigned to Advanced Placement (AP) and International Baccalaureate (IB) credits for all majors. Standard course equivalencies for each exam will be determined by "expert departments" in each college for each acceptable AP/IB score.

Under this procedure, students' AP or IB credit for a particular course will only go toward their degree requirements if allowed by the home department or college policies. Should a student decide to transfer to another major and/or academic unit within the university, AP/IB credit applicability to new degree requirements will depend upon the requirements of the new home department (or college). Students may only be granted credit for the Higher Level IB exams. This policy assumes no significant AP and/or IB exam changes. In the event of significant exam changes, students will be notified of any resulting policy changes no later than July 30 prior to their enrollment to take effect the fall of that year.

Credit is also given for Cambridge International/EdExcel Advanced Level courses. Learn more about AP, IB and Cambridge credits at www.cmu.edu/hub/registrar/registration/ap-transfer-credit.html (https://www.cmu.edu/hub/registrar/registration/ap-transfer-credit.html).

Rank in Class

Undergraduates at Carnegie Mellon pursue degrees in one or more of our ten schools or colleges. They may choose to pursue coursework, majors and minors within and between schools/colleges. In an institution where students' educational experiences are so varied, class rank is not a meaningful way to measure achievement.

Carnegie Mellon does not report nor record students' rank in class, rank in college and rank in department. Graduate school and/or employment requests that ask for a students' rank will be completed with the statement "Carnegie Mellon does not report rank in class."

Transcripts & Verifications

Transcripts

The student's official transcript is to be considered the official record for all degree(s), major(s), minor(s), and honors. The official Carnegie Mellon transcript includes both the undergraduate and/or graduate record(s). All transcripts come in individually sealed envelopes, unless otherwise specified. Transcript requests are not processed if the student has an outstanding obligation, financial or otherwise. We cannot accept phone or email requests and we are not able to fax a transcript under any circumstances.

Visit www.cmu.edu/hub/registrar/student-records (https://www.cmu.edu/hub/registrar/student-records/) for complete information, including how to order a transcript.

Verifications

Enrollment and degree verifications are available for currently enrolled Carnegie Mellon students and Carnegie Mellon Alumni. A verification officially confirms information about you. Please note that we cannot fax your QPA or verifications that contain anything besides the following:

- Name
- Local address
- Local phone number
- Email address
- Class
- College
- Department
- Dates of attendance
- Date(s) of graduation
- Degree(s) awarded

The most common reasons for requesting a verification are:

- Student loan agencies and insurance companies asking if a student is enrolled.
- Scholarship committees asking if a student maintained a certain QPA.
- Potential employers asking if a student graduated with a certain degree.

Online Verification Ordering

Currently enrolled Carnegie Mellon students may order enrollment verifications via Student Information Online (SIO) (https://s3.as.cmu.edu/sio/). Additional information can be found at www.cmu.edu/hub/registrar/student-records (https://www.cmu.edu/hub/registrar/student-records/).

Full-Time Status

Undergraduates who are registered as full-time students as of the end of the course add period (typically, the 10th regularly scheduled class day) are expected to remain full-time for the duration of the semester. Full-time is defined by a minimum of 36 units. Permission to drop below the 36 unit minimum must be granted by the student's associate dean. Undergraduates who are registered as part-time are also subject to the above deadlines to drop or withdraw from a course.

Students carrying a full-time course load at the end of the course add period (typically, the 10th regularly scheduled class day) are not ordinarily permitted to drop below 36 units after that time. Exceptions must be authorized by the student's associate dean.

Class Level Standing

Students should refer to the sections of the catalog pertaining to their college and/or department to determine the number of units required each academic year by their specific curriculum. Students must achieve passing grades in order to earn units; students do not earn units for incomplete or failed courses.

A first-year student becomes a second-year student after earning passing grades in three-fourths of the units required by their first-year curriculum.

A second-year student becomes a third-year student after earning the number of units required by their first-year curriculum plus three-fourths of the number of units for the second year.

A third-year student becomes a fourth-year student after earning the number of units required by their first-year and second-year curriculum plus three-fourths of the number of units for the third-year.

Classification of students is made only at the time of their first registration in any academic year and remains unchanged throughout the rest of that academic year.

Course Description Requests (for prior years)

Please note that University Archives does not have access to transcript and verification information. They maintain only the course description archives. If you call or email this office, your request will not be processed. Please contact:

Archives/Art Inventory Specialist
Carnegie Mellon University Libraries
4909 Frew St.
Pittsburgh, PA 15213
412-268-5021 (phone)
412-268-7148 (fax)

Graduation & Diplomas

Degree Requirements

Students are responsible for checking to ensure that the degree requirements (as listed in the appropriate catalog at the time of their matriculation) have been met. They may also refer to the Stellic (https://academicaudit.andrew.cmu.edu/) online degree audit application. If the degree requirements have been modified by College Council action, the student is responsible for checking to ensure that the modified requirements have been met.

To be eligible to graduate, undergraduate students must complete all residence and course requirements for their program with a cumulative Quality Point Average of at least 2.0. For undergraduate students who enrolled at Carnegie Mellon as a first-year and whose first-year grades cause the cumulative QPA to fall below 2.0, this requirement is modified to be a cumulative QPA of at least 2.0 for all courses taken after the first year. Note, however, the cumulative QPA that appears on the student's final transcript will be calculated based on all grades in all courses taken, including their first year. Some programs may have additional QPA requirements in order to graduate. Students are encouraged to confirm all graduation requirements with their academic advisor.

No student may receive a diploma until all financial obligations to the university have been met.

Residency Requirement

A candidate for the bachelor's degree must complete at the university a minimum of four semesters of full-time study, or the equivalent of part-time study, comprising at least 180 units of coursework. Note that these are minimum residency requirements applicable to all university undergraduates. Some of the university's colleges and departments have developed more restrictive requirements in this area. Students should consult that section of the catalog in which their college or department's academic regulations are presented for the residency requirements applicable to them. Deviation from these policies requires action by the dean of the student's home college.

Implications of Residency Requirements for transfer students seeking a second undergraduate degree: Students who received degrees from other universities could have up to 2 years of credits earned elsewhere applied to their Carnegie Mellon degree requirements and would need to meet Carnegie Mellon's Residency Requirement and complete at the university a minimum of four semesters of full-time study, or the equivalent of part-time study, comprising at least 180 units of coursework. Deviation from these policies will require action by the dean of the student's home college.

Diplomas

A Carnegie Mellon diploma is a student's certificate of accomplishment. The diploma is printed with the name the student approved within Student Information Online (SIO) , along with the student's primary degree and major (i.e., Bachelor of Arts in Creative Writing), and if applicable, additional major(s). Minors are not listed on a diploma, although they do appear on an official transcript.

Diplomas are distributed to graduates during or immediately following the May Commencement Ceremony. Certain circumstances will result in students receiving their diplomas at a later date; these students will be informed of this well before the ceremony. If a student is unable to attend the ceremony, diplomas will be mailed in the weeks following commencement. Diplomas are not available prior to the stated date of graduation. August and December graduates will receive their diploma via the mail.

The diploma is 14x17 inches and is marked with a multi-colored and gold seal.

Graduation with University Honors

In recognition of exemplary academic achievement as undergraduates, some candidates for undergraduate degrees will be named to the University Honors List. Each of the undergraduate colleges will select students for honors on the basis of a cumulative grade point average (typically when cumulative QPA is greater than 3.5) and/or recommendation of the faculty.

Standard Degree Terminology

Carnegie Mellon University offers a wide variety of programs; the opportunities vary greatly between and among the colleges. For the purposes of clarification, this section defines:

- standard degree terminology;
- changes to the existing degree declaration process;
- the existing procedure for creating new degrees, majors and minors.

Degree

Examples: B.S. (Bachelor of Science); M.F.A. (Master of Fine Arts); Ph.D. (Doctor of Philosophy)

Major

Field studied in greatest depth by fulfilling a department-determined set of course requirements. The primary major is the field in which the degree is granted.
Example: Creative Writing; Physics; Marketing
Students may pursue an additional major(s) in a single degree program.

Minor

Field(s) studied for educational enrichment by fulfilling a department-determined set of course requirements. Graduate students may not pursue minors. Minors are not listed on the diploma but appear on the student's transcript. The type of degree sought is determined by the major (that of the home department), not the minor. Examples: Film Studies; Game Design

Option

(Now referred to variously as track, option, etc.)
A specific area of study associated with the major or an additional major(s), which transforms the title of the major or additional major.
Examples: Civil Engineering (Biomedical Engineering Option) Physics (Computer Science Option)

Concentration

(Now referred to variously as track, option, etc.)
A specific area of study generally associated with a major or additional major, which appears only on the transcript.

Home College

The college into which the student was originally admitted or into which the student formally transferred.

Home Department

The department into which the student was originally admitted or the department offering the major which the student has declared.

Concurrent College/Department

College/department other than the home college/department, granting the second of multiple degrees, or offering the additional major(s) of the double or triple major, or minor.

Single Degree/Major

One diploma, stating the degree and the major field of study. Currently, the Statute of Limitations on earning an undergraduate degree is eight years.
Examples: B.A. in Psychology; M.S. in Chemistry.
Requirements: Fulfillment of all requirements of the home college.
Declaration: At least by registration time (early November), during the first semester of the junior year.
Certification: Home college, home department.

Major-Declaration Process

For undergraduates, depending on the student's college, the major is usually declared at the end of the first year or sophomore year. Departments enter the appropriate majors upon declaration.

For graduate students, the major is usually indicative of the department and is supplied by the department.

Joint Degree

Degree program offered between two or more colleges or departments.

Examples: B.H.A from the College of Fine Arts and the Dietrich College of Humanities and Social Sciences; M.S. in Colloids, Polymers, and Surfaces (Chemistry and Chemical Engineering).

Multiple Degrees

More than one degree granted by the university (whether simultaneous or sequential). The students receives one diploma for each degree. When awarded simultaneously, two degrees are referred to as dual degrees, three degrees as triple degrees. Multiple graduate degrees may be given in conjunction with an outside university.

Examples of how such degrees appear on the respective diplomas:

- Bachelor of Fine Arts in the field of Art; Bachelor of Science in the field of History
- Bachelor of Science in the field of Physics; Bachelor of Science in the field of Computer Science

Requirements: Multiple bachelor's degrees

Declaration: Undergraduates must declare at least by registration time (early November), during the first semester of the junior year.

To receive multiple bachelor's degrees the student must:

- satisfy all requirements for each degree.
- complete an aggregate number of units that exceeds, by at least 90, the minimum unit requirement for the degree with the smallest such

requirement (i.e., if one of the degrees requires a minimum of 360 units and the other requires 380 units, a total of at least 450 units (90 plus 360, the smallest of the two) is required to obtain both degrees).

- comply, for each degree, with the statute of limitations regarding the time at which units are earned.
- while working towards more than one degree simultaneously, designate one of the departments (and if necessary colleges) as the home college/department.

Additional Major

One degree, stating the major in the home department first and the additional major second. The type of degree given (B.A., B.S.) is determined by the major of the home department.

For example, a student whose home department is Physics:

This degree is valid: B.S. in Physics with an additional major in History

This degree is not valid: B.S. in History with an additional major in Physics

The intent of a double major is an in-depth understanding of two major fields. Students may pursue a second major in a field where the primary degree is different from the degree associated with the additional major: i.e., B.S. in Economics with an additional major in History.

Requirements: If the double majors involve two different colleges OR the same college, the student must fulfill:

- all requirements (including core) for the first major degree as defined by the home college;
- all major requirements (including core prerequisites) for the additional major;
- any specific requirements for double majors imposed by the department(s)/college(s) involved.

Declaration: At least by registration time (early November), during the first semester of the junior year.

Certification: Home college, home department; concurrent college (if any), concurrent department (if any).

Additional Majors

One degree, stating the major of the home departments first, the second and the third major afterwards. The type of degree sought (B.A., B.S.) is determined by the major in the home department.

For example, for a History student, this degree is valid: B.A. in History with additional majors in Professional Writing and in Hispanic Studies. This degree is not valid: B.A. in Professional Writing with additional majors in History and in Hispanic Studies.

Requirements: If the triple major involves two or three different colleges OR the same college, the student must fulfill all requirements listed for each additional major.

Declaration: At least by registration time (early November), during the first semester of the junior year.

Certification: department

Concurrent college (if any), concurrent department (if any)

Second concurrent college (if any), second concurrent department (if any)

Minor

One degree, stating the major first and the minor second (or third, if there is also (an) additional major(s) involved). The type of degree sought (B.A., B.S.) is determined by the major (that of the home department). Minors are not listed on the diploma, but appear on the transcript.

Examples: B.F.A. in Music Performance (Voice) with a minor in Theatre Arts; B.S. in Applied History with an additional major in Information Systems and a minor in Mathematics.

Requirements: The student would generally take 45 units pertaining to the minor, in addition to fulfilling all requirements for the major degree (as defined by the home college). The “minor” courses are negotiated between the student and the department certifying the minor.

Declaration: At least by registration time (early November), during the first semester of the junior year.

Certification: department

Concentrations (Tracks, Options, Specializations, Area Cores, etc.)

These concentrations will not be considered part of the student's degree title unless the concentration is included as part of the major or (an) additional major(s) field title.

Additional Majors/Minors Declaration Process

For undergraduates, all variations on a student's intended degree and major field must be declared by the end of the first semester of the student's junior year. Having already declared a major, students should be well prepared by this time to choose additional majors and/or minors.

It is assumed that by these proposed deadlines, the student will have taken a majority of degree requirements and electives. The student can then, in conjunction with an advisor, review their course history and decide which options may or may not apply towards a supplemental degree and field(s), and then receive a detailed curriculum for attaining the additional desired degree, major or minor. The student should then notify the college/department offering the additional program. Upon receipt of this notification, the college/department will update the Student Information System which will allow this information to be reflected in the Commencement System for graduation. This procedure ensures that when a student is expected to graduate, all degree/major information is immediately accessible, and certification of the degree is simplified.

Multiple Degrees Involving Graduate Degrees

Policies involving multiple graduate degrees or a graduate/undergraduate degree program or sequence are dictated by each college involved.

Examples: M.S. in Public Management and Policy and the degree of Juris Doctor (Heinz College/University of Pittsburgh School of Law).

Declaration: Undergraduates: at least by registration time (early November), first semester junior year.

Declaration: Graduates: upon admittance OR by the end of the semester preceding the expected graduation date.

Certification: Home college, home department and concurrent college (if any), concurrent department (if any).

Degree Certification

undergraduate PROGRAM STANDARD DEGREE REQUIREMENTS & DEGREE CERTIFICATION

Carnegie Mellon undergraduate students are expected to complete their program of study within eight semesters of full-time enrollment, or 10 semesters for undergraduate students in the Bachelor of Architecture (B.Arch.) program. The standard undergraduate program of study is grounded in a primary degree and its requirements, and may be complemented by an additional major(s) or minor(s) as part of the student’s academic plan or as a requirement of the primary major. Upon completion of all primary degree requirements within the program of study in the standard number of eight semesters (or 10 for B.Arch.), the degree will be certified by the student’s academic program in the semester in which the student completes the requirements.

Early Completion

Students who complete their primary degree requirements within their program of study in fewer than eight semesters (or 10 for B.Arch.) may have their degree certified upon the completion of all requirements in consultation with their academic advisor(s).

Longer-than-Standard Completion

Longer-than-standard degree completion may occur due to academic interruptions in making progress toward the degree as defined by the academic program and/or the Student Financial Aid Satisfactory Academic Progress policy, interruptions of full-time study or progress toward the degree due to serious, documented medical issues, or other unusual or unforeseen circumstances. Students who complete their primary degree requirements within their program of study in more than the standard number of semesters will be certified in the semester in which they have completed their primary degree requirements, pursuant to close and regular consultation with their academic advisor(s).

Additional Guidance for Students

Program of study. Students seeking guidance about their program of study and degree requirements should consult with their academic advisor and/or appropriate associate dean.

Financial aid and student account. Students are expected to make normal progress toward their degree in order to graduate within the standard timeframe for their program of study. Under U.S. Federal Title IV regulations, student eligibility for federal financial aid is contingent upon enrollment in and successful completion of courses that are counted as credit toward their current degree program. To receive the maximum amount of federal and state financial aid for which they may be eligible, students must enroll each semester in at least 36 units that count toward their current degree level. CMU institutional undergraduate grants support undergraduate degree completion and on-time graduation; institutional undergraduate grants for students in undergraduate programs and in integrated undergraduate and master's degree programs are renewable for eight semesters (and 10 for B.Arch.). (See separate guidance regarding integrated bachelor-master's degree programs.)

Students should consult with their designated college liaison in The HUB regarding billing and financial aid, particularly for early completion, longer-than-standard completion, or integrated undergraduate and master's degree programs.

International students. Immigration status for students in F-1 and J-1 non-immigrant status is tied to making normal progress toward completing degree requirements. Therefore, F-1 and J-1 students who are considering completing their degree requirements early, anticipating longer-than-standard completion, or moving from an undergraduate to a graduate student classification (integrated undergraduate-graduate study), should consult with their designated advisor in the Office of International Education (OIE) to ensure compliance with immigration regulations.

Guidance for Academic Advisors and Deans

Advisors and associate deans may direct questions regarding degree certification, norms or exceptions to the University Registrar or to the Vice Provost of Education.

Integrated Bachelor & Master's Degree Programs STANDARD DEGREE REQUIREMENTS & DEGREE CERTIFICATION

The integration of bachelor and master's degree programs ("IBM" programs) benefits CMU students who elect to maximize their use of time and academic energy to blend their undergraduate studies with master's-level study in close combination, in an integrated program of study at CMU. Some CMU departments and programs have developed integrated options for students in response to student desires for such opportunities and to enliven their graduate programs with students who are well-acclimated to the rigor and demands of the CMU educational experience.

General Information

Carnegie Mellon students in integrated bachelor-master's programs are expected to complete their degree requirements within a standard length of time for their full-time program of study as outlined in the Undergraduate Catalog and relevant Graduate Student Handbook. This document describes several standard models for the CMU integrated bachelor-master's degree programs, some of which involve acceleration of either the undergraduate or the graduate degree component (or both) within the integrated program designs. Each CMU integrated program offers specific, pre-determined model(s) of integrated study reflecting one of the following:

- 4+0 meaning that a student will complete both undergraduate and master's degree coursework in eight semesters (four years) of full-time study. This model generally applies when the undergraduate and graduate field of study are the same, such as an undergraduate and master's degree in Chemistry or Mathematics.
- 3-1-1 meaning three years of full-time undergraduate coursework, followed by one year of integrated undergraduate and graduate study, and one year of exclusively master's level coursework for a total of five years of full-time study. And example would be undergraduate degrees integrated with Heinz College or Tepper graduate degree programs. The undergraduate degree generally is completed in eight semesters of full-time study (or less.)
- 4+1 semester meaning eight semesters (four years) of full-time undergraduate coursework including integration of some master's level courses, followed by one semester of exclusively master's level coursework for a total of four and a half years. The undergraduate degree generally is completed in eight semesters of full-time study (or less.)
- 4+2 semesters meaning eight semesters (four years) of full-time undergraduate coursework including integration of some master's level courses, followed by two semesters of exclusively master's level coursework for a total of five academic years. The undergraduate degree is completed in eight semesters of full-time study (or less.)
- 4+3 semesters meaning eight semesters (four years) of full-time undergraduate coursework including integration of some master's level courses, followed by three semesters of exclusively master's level coursework for a total of five and a half academic years. The undergraduate degree is completed in eight semesters of full-time study.
- 5+1 for architecture meaning five years of Bachelor of Architecture (B.Arch.) undergraduate coursework followed by two semesters of full-time master's level coursework for a total of six academic years. The B.Arch. undergraduate degree generally is completed in 10 semesters.

The standard undergraduate program of study is grounded in a primary degree and its requirements, and may be complemented by an additional major(s) or minor(s) as part of the academic plan. Some students decide to apply for one of CMU's several integrated degree programs to complement their undergraduate degree with an integrated or accelerated master's degree. Depending on the model of the integrated program, when an undergraduate student applies to an IBM program, they recognize that the standard for undergraduate study will be eight semesters (or 10 for B.Arch.), plus one, two, three or four additional semesters of full-time graduate-level study (except for the 4+0 model, above) to complete the master's degree.

CMU students in most IBM programs are considered to be undergraduates until they have completed the requirements for their bachelor degree at which point they are certified by their undergraduate academic program; this typically occurs at the time determined to be the standard for their integrated program following a successful seven or eight semesters (or 10 for B.Arch.) of full-time enrollment, depending on the design of their integrated program. However, in one rare model, the integrated program design holds the bachelor degree certification to be given concurrently with the master's degree in the ninth or tenth semester of full time enrollment.

Early Completion of Undergraduate Degree

An IBM student who has completed all undergraduate degree requirements in fewer than the standard number of semesters for their program may request an early undergraduate degree certification from their undergraduate program, in close consultation with their academic advisor(s). This situation, while possible, is not common due to the necessity of staying on track for both undergraduate and master's degree programs in an integrated manner.

Movement from Undergraduate to Graduate Student Classification

Students in an IBM program who are certified as having completed their undergraduate degree – typically in the number of semesters that is the standard for their integrated program – then will be classified as a graduate student at CMU, and are expected to complete their graduate degree requirements within the standard length of time for their integrated program of study. Students should be aware of and plan for financial implications, including financial aid, and/or F-1/J-1 non-immigrant implications due to the change of level when moving from undergraduate student status to graduate student status at CMU. (See details below.)

Standard for Graduate Component of IBM Student/Program

Upon completion of the graduate program degree requirements in the standard period of study, the graduate degree will be certified in the semester in which the student completes the requirements by the student's graduate program.

Early Completion of Graduate Degree Requirements

Early completion of the graduate degree requirements. Graduate students who consider the completion of all degree requirements in less than the standard length of time for their program of study must consult with their degree-granting program or department to determine if early degree certification is allowed academically and under what circumstances.

Incomplete Graduate Degree Requirements

In some cases, students in an IBM program may withdraw from the graduate component of the program of study and, therefore, will not be certified or awarded the graduate degree. Any such withdrawal decision also may require close consultation with the undergraduate advisor to determine eligibility for undergraduate degree completion and certification if the undergraduate degree is not already certified.

Extended or Longer-than-Standard Graduate Degree Completion

Longer-than-standard degree completion may occur due to academic interruptions in making progress toward the degree as defined by the academic program, interruptions of full-time study or progress toward the degree due to serious, documented medical issues, or other unusual or unforeseen circumstances.

IBM students who require longer than the standard time to complete their graduate degree requirements are expected to remain in close contact with their graduate program, and will be certified at the end of the semester in which they have completed their degree requirements. Students shall reference the CMU Policy on Master's Student Statute of Limitations (https://www.cmu.edu/policies/student-and-student-life/masters-students-statute-of-limitations.html) regarding guidelines and restrictions which place an upper limit on the maximum length of time allowable for master's degree completion and certification.

Additional Guidance for Students

Program of study. Students seeking guidance about their program of study and degree requirements should consult with their academic advisor and/or appropriate associate dean.

Financial aid and student account. Students are expected to make normal progress toward their degree in order to graduate within the standard timeframe for their program of study. Under U.S. Federal Title IV regulations, student eligibility for federal financial aid is contingent upon enrollment in and successful completion of courses that are counted as credit toward their current degree program. To receive the maximum amount of federal and state financial aid for which they may be eligible, students must enroll each semester in at least 36 units that count toward their current degree level. CMU institutional undergraduate grants support undergraduate degree completion and on-time graduation; institutional undergraduate grants for students in undergraduate programs and in IBM programs are renewable for eight semesters (and 10 for B.Arch.).

Students should consult with their designated college liaison in The HUB regarding billing and financial aid, particularly for early completion, longer-than-standard completion, or integrated bachelor and master's degree programs.

International students. Immigration status for students in F-1 and J-1 non-immigrant status is tied to making normal progress toward completing degree requirements. Therefore, F-1 and J-1 students who are considering completing their degree requirements early, anticipating longer-than-standard completion, or moving from an undergraduate to a graduate student classification (integrated undergraduate-graduate study), should consult with their designated advisor in the Office of International Education (OIE) to ensure compliance with immigration regulations.

Guidance for Academic Advisors and Deans

Advisors and associate deans may direct questions regarding degree certification, norms or exceptions to the University Registrar or to the Vice Provost of Education.

Academic Actions

Each college may have its own regulations and procedures regarding academic actions, but in general, the following apply to all undergraduate students.

Student Suspension/Required Withdrawal Policy

Policy Statement

University Suspension is a forced, temporary leave from the university. There are three types of suspension for students that apply to both graduate and undergraduate students:

- **Academic Suspension** is the result of poor academic performance or violation of academic regulations and is imposed by the student's college or academic department (see university and college academic policies).
- **Disciplinary Suspension** is the result of serious personal misconduct and is imposed by the Office of Student Affairs (see The Word/Student Handbook (https://www.cmu.edu/student-affairs/theword/)).
- **Administrative Suspension** is the result of failure to meet university financial obligations or failure to comply with federal, state or local health regulations and is imposed by Student Financial Services (see Student Financial Obligation Terms (https://www.cmu.edu/sfs/billing/sfo.html)).

Suspended students may not:

- register for courses
- attend classes
- live in residence halls or Greek housing
- use campus facilities, including athletic facilities, libraries and computer clusters
- participate in student activities
- be members of student organizations
- have student jobs*

**Students on academic suspension may have a summer campus job if they accepted the job before they were suspended.*

Employment

Although suspended students may not hold student jobs, students on academic suspension may, under certain circumstances, have a non-student job with the university; students on disciplinary or administrative suspension may not.

To have a non-student job, students on academic suspension must receive approval from their associate dean (undergraduate students) or department head (graduate students) to ensure that the job will not violate their suspension terms. Students in violation of this will lose their degree student status, meaning they would have to reapply for admission to Carnegie Mellon through either the Office of Undergraduate Admission or the appropriate graduate department.

Transfer Credit

Suspended students may take courses elsewhere; however, they may receive transfer credit only if their college's and department's policies allow this.

Appeals

To appeal any action of this policy, the student may write to the following individuals:

- Academic Suspension: Associate dean (undergraduate students) or department head (graduate students)
- Disciplinary Suspension: Dean of Student Affairs
- Administrative Suspension: Vice Provost for Enrollment Management and the Dean of Student Affairs, in consultation with the student's associate dean

Returning from Suspension

In order to return from a suspension, a student must have the following approval:

- Academic Suspension: Associate dean (undergraduate students) or department head (graduate students)
- Disciplinary Suspension: Dean of Student Affairs
- Administrative Suspension: Vice Provost for Enrollment Management and the Dean of Student Affairs, in consultation with the student's associate dean

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Procedure for the Appeal of Grades & Academic Actions

In the event a student believes an assigned grade or an imposed academic action is incorrect or not appropriate, the student may follow the processes outlined below to seek a prompt and equitable resolution of the matter.

If a student believes a grade has been incorrectly assigned, the student should:

1. Present the case to the faculty member responsible for the course, providing all supporting data concerning the nature of the discrepancy.
2. If, after a decision is rendered, the student believes that their concerns have not been adequately resolved, the student may pursue a formal appeal with the department responsible for the course. To appeal to the department, a student must present a written statement detailing the grounds for the appeal with appropriate documentation to the head of the department responsible for the course. This appeal must be submitted within seven (7) days of receipt of the faculty member's decision. The department head will provide a written decision, including the basis for it, within thirty (30) days, or as soon thereafter as practical.
3. If the student is not satisfied with the department head's resolution, the student may pursue the appeal at the college level. To appeal at the college level, the student must present copies of all documents originally sent to the faculty member and department head, along with a formal letter of appeal, to the dean of the college responsible for the course. This appeal must be submitted within seven (7) days of receipt of the department head's decision. The dean, or the dean's designate, will review the appeal and will render a written decision, including the basis for it, within thirty (30) days, or as soon thereafter as practical.

If a student believes an academic action is inconsistent with the policies of the college or merits additional review, a student should:

1. Submit a formal written appeal, as specified in the initial academic action, to the associate dean of the college responsible for the decision, with a copy to the dean, requesting review of the action including all relevant materials to substantiate their case and support their concerns.
2. The dean of the college, or the dean’s designate, will review the appeal and issue a decision and the basis for it within thirty (30) days.

If, after carrying out the steps of either process described above, the student believes that the matter has not been adequately resolved, or if no decision has been rendered by the appropriate date, the student may appeal at the university level. To appeal at the university level, the student must present copies of all previously submitted documents and a formal letter of appeal to the Provost. The Provost or another designated university officer will respond in writing with a final resolution, including the basis for it, within thirty (30) days, or as soon thereafter as practical.

Other Academic Regulations

English Fluency for Non-Native English Speakers

To be successful at Carnegie Mellon University, students who are nonnative speakers of English need to begin their undergraduate work with a strong foundation in academic English and a high level of proficiency with speaking, listening, reading and writing in English. The importance of English language abilities cannot be overstated since there are no basic English as a Second Language (ESL) courses at Carnegie Mellon. All students will have sufficient English language proficiency to be able to participate fully in the academic work and to interact in daily life outside of the classroom.

Students' English proficiency will enable them to handle the demands of academic work, including the ability to comprehend, process, and master complex material presented in English, both in written and spoken form. Students will be able to communicate their ideas and questions to faculty, classmates, and others, in a classroom environment that is often highly participatory. For example, many classes require group discussion, team projects, oral presentations, and/or independent research. In addition to proficient English skills, studying in a new culture requires openness and flexibility to adapt to a new, and often very different, academic system.

To assess the language of non-native English speaking applicants, a minimum TOEFL score of 600 (paper based, PBT), or 100 (internet based, iBT) has been established as the standard for admission. This minimum score indicates that an applicant has the fundamental building blocks of language needed for academic tasks and for continued language development. Since neither the PBT or iBT versions of TOEFL access speaking, students who take these tests should additionally seek feedback on their speaking skills and work to improve conversational skills before beginning academic work.

Exchange Students

Each term, Carnegie Mellon welcomes exchange students from partner institutions around the world. Exchange students enrich the learning experience at Carnegie Mellon and are expected to be full participants in the curricular and meta-curricular life. Therefore, their admission should adhere to the English language guidelines described above. Exchange students submit standardized English language testing scores (such as the TOEFL) as part of the Exchange application process, and present the same high level of English language abilities as degree-seeking students. With exchange students, high-level English abilities are particularly critical since academic, personal and extracurricular experiences must be maximized in a short period of time, sometimes only four months in duration.

Withdrawal of a Degree

The university reserves the right to withdraw a degree even though it has been granted should there be discovery that the work upon which it was based or the academic records in support of it had been falsified. In such a case the degree will be withdrawn promptly upon discovery of the falsification.

Information for Graduating Students

Graduating students may wear one stole ONLY with their academic regalia. Students are certainly permitted to receive/purchase more than one stole if they are a member of multiple organizations that issue stoles and may choose to wear a particular stole to the main commencement ceremony and another to their diploma ceremony.

Graduating students who are a member of a club/organization that issues a pin to designate affiliation are permitted to wear more than one pin with the academic regalia in addition to one stole.

Retention of Student Work

The university reserves the right in all colleges to retain indefinitely any student work the faculty may select. All work not retained by the university must be claimed at the time specified on the bulletin boards (or other forms of communication) of the department concerned; otherwise, the work will be destroyed.

Degree Statute of Limitations

www.cmu.edu/policies/student-and-student-life/ug-statute-of-limitations-student.html (https://www.cmu.edu/policies/student-and-student-life/ug-statute-of-limitations-student.html)

All units required for an undergraduate degree, whether earned in residence, transferred from another institution or granted via advanced placement, must have been earned within eight years of the date on which the degree is granted. This statutory period can be extended by the Dean of the student's college under the following conditions:

- the courses taken prior to the statutory period still represent a reasonable part of the student's total academic program;
- the prior courses provide adequate preparation for courses which must still be taken to fulfill the degree requirements;
- there is a legitimate reason(s) for the student not completing the academic program within the statutory period.

A request for a waiver of the statute of limitations must be submitted to the dean of the student's college. The request for a waiver should address all of the above conditions for an extension. For cases in which a waiver is granted, the waiver covers specific courses and is intended for a specific period during which the program must be completed.

New Degree, Major, or Minor

Departments proposing new degrees, majors, additional majors, and/or minors must complete a New Academic Program Process (NAPP Step 2) form. This should include any and all notations to the university diploma and/or transcript (new degrees, majors, minors, options). Departments proposing to offer a new degree, major, additional major and/or minor must follow university policies for approval as follows:

- Document the program by completing the New Academic Program Process (NAPP Step 2) form. Departments proposing new degrees and majors must complete this form and attach course descriptions, curriculum proposal, list of present faculty who will support the program, and verify the availability of other units' courses. This documentation must indicate the starting semester for the program, and in the case of new majors, also indicate if it is available only as a major/additional major/minor, or in combination.
- Receive department approval.
- Receive dean and College Council approval.
- Submit all program documentation complete with College Council approval to the Vice Provost for Education. New majors or degrees will not be processed without the approval of the Provost's Office.
- The Provost's Office will approve or deny, and inform the sponsoring department and Enrollment Services.
- The department may then publicize and offer the program for student enrollment.

Inter-campus Undergraduate Student Transfer Process

Undergraduate students enrolled at either the Pittsburgh or Doha campuses of Carnegie Mellon University may request consideration for internal transfer to the other undergraduate campus through a formal application process. Students must be in good standing with a QPA of 3.0 or higher, and must have completed two full semesters at their campus of initial enrollment. The first step in the process is consultation with the student's home campus Associate Dean for Education to fully discuss their potential interest in a transfer. Students will be required to document their interests and offer a compelling academic and/or personal rationale to support their inter-campus transfer request application. The deadline for application is the first day of the spring semester for transfer in the subsequent fall semester.

University Policies

A University Policy is a rule that has been officially sanctioned by the president of Carnegie Mellon University and that generally has university-wide applicability. A policy may include governing principles, may either mandate or constrain action, may ensure compliance with laws, or may mitigate the university's risk. Broadly, a policy is either academic or administrative in scope and application and must be approved by the president (and Board of Trustees as required), in order to become official University Policy.

Additional University Policies and information may be found at www.cmu.edu/policies (https://www.cmu.edu/policies/).

Academic Integrity

www.cmu.edu/policies/student-and-student-life/academic-integrity.html (https://www.cmu.edu/policies/student-and-student-life/academic-integrity.html)

Students at Carnegie Mellon are engaged in intellectual activity consistent with the highest standards of the academy. The relationship between students and instructors and their shared commitment to overarching standards of respect, honor and transparency determine the integrity of our community of scholars. The actions of our students, faculty and staff are a representation of our university community and of the professional and personal communities that we lead. Therefore, a deep and abiding commitment to academic integrity is fundamental to a Carnegie Mellon education. Honesty and good faith, clarity in the communication of core values, professional conduct of work, mutual trust and respect, and fairness and exemplary behavior represent the expectations for ethical behavior for all members of the Carnegie Mellon community.

Policy Statement

In any manner of presentation, it is the responsibility of each student to produce her/his own original academic work. Collaboration or assistance on academic work to be graded is not permitted unless explicitly authorized by the course instructor(s). Students may utilize the assistance provided by the Student Academic Success Center and the Academic Resource Center (CMU-Q) unless specifically prohibited by the course instructor(s). Any other sources of collaboration or assistance must be specifically authorized by the course instructor(s).

In all academic work to be graded, the citation of all sources is required. When collaboration or assistance is permitted by the course instructor(s) or when a student utilizes the services provided by the Student Academic Success Center and the Academic Resource Center (CMU-Q), the acknowledgement of any collaboration or assistance is likewise required. This citation and acknowledgement must be incorporated into the work submitted and not separately or at a later point in time. Failure to do so is dishonest and is subject to disciplinary action.

Instructors have a duty to communicate their expectations including those specific to collaboration, assistance, citation and acknowledgement within each course. Students likewise have a duty to ensure that they understand and abide by the standards that apply in any course or academic activity. In the absence of such understanding, it is the student’s responsibility to seek additional information and clarification.

Policy Violations

Cheating occurs when a student avails themselves of an unfair or disallowed advantage which includes but is not limited to:

1. Theft of or unauthorized access to an exam, answer key or other graded work from previous course offerings.
2. Use of an alternate, stand-in or proxy during an examination.
3. Copying from the examination or work of another person or source.
4. Submission or use of falsified data.
5. Using false statements to obtain additional time or other accommodation.
6. Falsification of academic credentials.

Plagiarism is defined as the use of work or concepts contributed by other individuals without proper attribution or citation. Unique ideas or materials taken from another source for either written or oral use must be fully acknowledged in academic work to be graded. Examples of sources expected to be referenced include but are not limited to:

1. Text, either written or spoken, quoted directly or paraphrased.
2. Graphic elements.
3. Passages of music, existing either as sound or as notation.
4. Mathematical proofs.
5. Scientific data.
6. Concepts or material derived from the work, published or unpublished, of another person.

Unauthorized assistance refers to the use of sources of support that have not been specifically authorized in this policy statement or by the course instructor(s) in the completion of academic work to be graded. Such sources of support may include but are not limited to advice or help provided by another individual, published or unpublished written sources, and electronic sources. Examples of unauthorized assistance include but are not limited to:

1. Collaboration on any assignment beyond the standards authorized by this policy statement and the course instructor(s).
2. Submission of work completed or edited in whole or in part by another person.
3. Supplying or communicating unauthorized information or materials, including graded work and answer keys from previous course offerings, in any way to another student.
4. Use of unauthorized information or materials, including graded work and answer keys from previous course offerings.
5. Use of unauthorized devices.
6. Submission for credit of previously completed graded work in a second course without first obtaining permission from the instructor(s) of the second course. In the case of concurrent courses, permission to submit the same work for credit in two courses must be obtained from the instructors of both courses.

Procedures for dealing with allegations of these policy violations are detailed in the university’s Academic Disciplinary Action Procedures, which are published in The WORD student handbook (https://www.cmu.edu/student-affairs/theword/). Periodic review of these procedures will be overseen by the Dean of Student Affairs or her/his designee in consultation with Faculty Senate and the relevant student governing bodies. Any amendments to these procedures are subject to the approval of Faculty Senate. Additional guidelines and procedures for graduate students may exist at the college/department/program level, in which case they are communicated in the college/department/program graduate student handbook.

Computing Policy

www.cmu.edu/policies/information-technology/computing.html (https://www.cmu.edu/policies/information-technology/computing.html)

Statement

The purpose of this policy is to set forth guidelines so that members of our community may use the campus network and computing facilities in ways that are responsible and respectful of privacy. This policy sets forth the university’s expectations of acceptable behavior on the part of computer systems users at Carnegie Mellon by providing guidelines for appropriate use of computing and related communication systems and examples of inappropriate use. These standards of acceptable behavior also extend beyond the campus community into the Internet. Just as it is unacceptable to violate others’ rights to privacy, property and resources within Carnegie Mellon, it is also unacceptable to violate those rights on systems that are not at Carnegie Mellon but are accessible through Carnegie Mellon’s connection to the Internet.

This policy applies to all users of Carnegie Mellon computing systems, including students, faculty and staff, and any others granted the use of university computing resources. It applies to the use of all computing facilities owned, leased, operated or contracted by Carnegie Mellon University. As used in this policy, terms such as “computing,” “computing/communications systems,” “computing resources,” etc., refer to all computers, communication systems, and peripherals, software, telephones and systems with similar functions, which are owned by Carnegie Mellon, or which utilize Carnegie Mellon infrastructure such as telephone lines or computer networks.

Although this policy does not attempt to deal specifically with legal issues, university members are responsible to act in compliance with the law, including any federal, state and local laws governing computer and telecommunications use, as well as all other applicable university policies.

Privileges and Responsibilities

Every member of the Carnegie Mellon community who uses computing and related communications systems at Carnegie Mellon, or systems that belong to Carnegie Mellon or which rely on Carnegie Mellon's infrastructure has the responsibilities described in this policy. This includes members of the Carnegie Mellon community who have restricted privileges, such as alumni who may have electronic mail forwarding access, but no access to "login" resources. Individuals with personally-owned computers, but who rely upon the university network to connect those computers (either through an on-campus or remote network connection, such as Ethernet, wireless, dialup, DSL) are expected to abide by the policies set forth in this document. Personally-owned computers operating in stand-alone mode or networked through a non-university connection are not covered under this policy, but those users are encouraged to consult the usage policies set forth by their Internet Service Provider.

A fundamental premise of this policy is that anyone sharing computing resources with other individuals should behave as a reasonable, mature and ethical person. The user must recognize that computer systems and networks do not exist in some special rule-free environment; on the contrary, use of computers is a form of communication, and every component of a computing environment and every piece of information it contains belong to the university, the university community as a whole, or some individual or group within that community.

Access to Carnegie Mellon's computing resources is contingent upon being a member of the university community and adhering to university and Computing Services policies, guidelines and procedures, including this policy. Misuse may result in the loss of access and/or university disciplinary action. For some users and certain systems, access may be authorized by specific departments, research centers or other organizations affiliated with Carnegie Mellon. In such cases, any department- or group-specific policies and guidelines must be adhered to when using resources provided by the department or group. This is in addition to university policies and Computing Services guidelines and procedures.

Any user who suspects a violation of the University's computer use policies, or who has knowledge of potential vulnerabilities or security loopholes in a system or network at Carnegie Mellon, should immediately notify the Computer and Network Security Coordinator or abuse@andrew.cmu.edu.

Maintain the Security and Confidentiality of your Account

Users assume personal responsibility for the use made of their computer accounts. This responsibility begins with selecting a secure password, and involves maintaining the confidentiality of that password and changing the password regularly in order to assure the continued security of your account. For guidance in selecting a secure password, see Managing Your Andrew Password. If you believe that someone has made unauthorized use of your account, you should change your password immediately and report the incident to the Computer and Network Security Coordinator or abuse@andrew.cmu.edu.

Respect for Others' Property and Privacy Rights

Users are responsible to respect copyright agreements and intellectual property ownership. Any material that is the work of another, whether explicitly copyrighted or not, should not be distributed by a user without appropriate acknowledgement and/or permission of the creator; unless permission has been granted by the owner of copyright protected materials, distribution of copyright protected material via the university network or computer systems is prohibited. So while the university has been granted permission by software vendors to distribute certain software packages via the network, it is not generally permissible for individual users to distribute that same software to others via the university network or computer systems. See the sections in this policy on Misuse and Inappropriate Behavior. While there may be cases in which property rights to particular programs, data, etc., are ambiguous or in dispute, the user must assume that any information not created by themselves belongs to someone else and must respect that person's privacy and property rights to that information. (In certain situations, even information created by the user may not belong to that user but rather to the university or others.) This policy is not intended to limit "fair use" as permitted under the Copyright Act and users having questions about whether a particular use constitutes a "fair use" may consult the General Counsel for advice.

Improper/Illegal Communications

Any communications that would be improper or illegal on any other medium are equally so on the computer: libelous material, obscene messages, harassment, forgery, threats, etc. However, this is not intended to restrict the free expression of ideas. Communication conducted in accordance with the university policy on Free Speech and Assembly and Controversial Speakers and with the statement on Academic Freedom and Responsibility enunciated in the Appointment and Tenure Policy of Carnegie Mellon University will not be considered a violation of this policy. For further guidelines, see also the university policy on Separation of Individual's and Institution's Interests.

Responsible Sharing of Resources

Where a resource such as memory, CPU time or access to network resources belongs to the whole community collectively, it must be shared.

It is unacceptable to make such excessive use of system or network resources that other users cannot obtain access. Examples include excessive use of CPU time during a period of heavy use on a timesharing system, excessive use of disk space on a system that does not limit such utilization, the use of an excessive amount of network bandwidth in an environment of networked computers, and any activity that makes a system unusable or significantly degrades performance for others. A novice user might be unaware that a particular action constitutes "excessive use" but, without doubt, once a system administrator makes them aware of the fact that such an action is unreasonable, that user will be held responsible for any further such infractions. If you are unsure whether your needs constitute excessive use, contact the system administrator. Similarly, if you need an unusual amount of disk space, CPU time or other resources, check with the system administrator to find out whether this use can be accommodated, rather than risk interfering with the work of others on the system.

Risks of Data Loss and Data Persistence

Although the university will make efforts to secure the network and university controlled servers from abuse and damage, it cannot guarantee against data loss by a student, faculty, member or staff, either on a university-operated or an individually-owned computer.

Users should know that even those files that they have "deleted" using the appropriate procedures in the application or operating system, may indeed be recoverable if they exist in a system backup file or other persistent form. If the university is asked to recover such data by subpoena, it must cooperate, and data that the user believes to have been destroyed may be recovered in the process.

Personal Use

While the university makes computer resources available primarily to achieve its goals of education and research, and for administrative activities, it realizes the need to encourage the personal use of computing for the convenience of the campus community. Thus, it is reasonable to allow the use of computing resources for computer mail, document preparation, personal or course Web page publication, or other activity that can facilitate convenience or enhance productivity, to the extent that the activity is within the limits described by Responsible Sharing of Resources. Any personal use of computing resources related to operating a personal business or commercial enterprise is prohibited unless permission to do so has been specifically granted by the provost or the provost's designee.

We do recognize the difficulty of distinguishing whether certain cases of "personal use" are allowable, such as activities that result in personal financial gain (e.g. checking stock prices online), relate to a commercial business (e.g. university-sponsored technology transfer efforts), or support (but do not constitute operating) a personal business (i.e., a student developing a business plan or a faculty member writing a report for a consulting engagement outside the university). In such cases, we rely on individuals to be responsible and judicious in the use of university's shared computing resources. In particular ensuring:

- appropriate use of resources (e.g. any such work is completed outside of university time and does not utilize shared resources such as CPU cycles or network bandwidth to a degree that adversely impacts academic or research activities);
- appropriate use of licenses (e.g. do not use software procured with academic use licenses for commercial applications or development, unless the license explicitly permits such use);
- appropriate marketing (e.g. no creation of ".com" domains within Carnegie Mellon's "edu" domain, no advertising services and products using Carnegie Mellon email accounts, and no advertising using web pages on Carnegie Mellon servers (any server with a .CMU.EDU host name).

In cases of questionable personal use of resources, you may contact advisor+@andrew.cmu.edu to determine whether a particular activity is permissible.

We reserve the right to restrict personal use of university systems and networks by an individual or by the community at large, if the use of resources for such activities becomes excessive. If you need unlimited access to computer networks for private or business purposes, you can subscribe to a commercial service.

For information regarding the use of resources to produce intellectual property and profit from the development of such property see Carnegie Mellon University's Intellectual Property Policy and the Policy on Conflict of Interest/Commitment.

Privacy

The user must presume that the contents of any other users' directory are private unless expressly designated otherwise, just as one would presume that the contents of someone's apartment or office are private. The only exceptions to this rule are: that in some environments, files such as "plan files" may be considered public even if the user has not expressly designated them as such; and that some services such as web pages and anonymous or "guest access" ftp services may be considered to be public, but only for those areas not protected by password and which are "obviously" public. An unprotected account or shared device (such as a shared disk on a networked computer) are not considered to be public unless the name or service expressly indicates that it is. In such cases, any files or other data which would appear to be private in nature, by virtue of the file name or data stored, even if "publicly accessible" should be considered to be private. The user accessing such files has a responsibility to ask the owner of the files or service if the files are intended to be publicly accessible before the user does more than a "cursory glance" sufficient to cause the question.

A user can explicitly grant access to his or her directories, files or to services run from his or her systems. However, users who issue general or vague invitations to browse through their files incur a special obligation to protect any material that they do not wish others to see. Indeed, all users are urged to maintain protection levels on their files consistent with the access they are actually willing to give to other users.

Access to Faculty Data

Electronic data on a faculty member's account, whether stored on a computer in the faculty member's office or elsewhere under the proprietary control of that faculty member, may not be examined, i.e., the contents of the data read by a person, without the faculty member's consent, except in cases of emergency or in response to a valid subpoena, search warrant, or order of a court. Posting of data by a faculty member on servers available to the public or to students shall be understood to imply consent, and electronic access given to specific parties by the faculty member will likewise imply consent for those parties to access permitted data. Emergencies may include, for example, but are not limited to, the death, incapacity or disappearance of the faculty member, or the search for and examination of files used for apparently malicious activity in an account which endangers the integrity of shared computers, the network, or other aspects of the university's computing infrastructure.

Only specifically designated individuals are permitted to determine what passes for an "emergency." Such individuals may be specifically designated, or may be designated by job position/description. All assignments for individuals or positions will be done by Provost or by a designate of the Provost.

Whenever possible and legally permissible, notification must be given to the faculty member whose data are subject to subpoena, search warrant, or order of court prior to compliance therewith, and, whenever possible and legally permissible, sufficient time must be allowed, before intrusion, to allow the faculty member to file a motion to quash. Information obtained from an examination warranted by an emergency cannot be used as evidence in University sanctions of any faculty member, and cannot be released to the public, or to the university community or to public officials, except as such releases are essential to resolution of the emergency, or constitute evidence of a crime concealment of which would obstruct justice, and in the latter case release may only be to appropriate law enforcement officials. Any intrusion by an employee of the University into a faculty member's electronic data must be reported to the faculty member as soon as possible, and within five days of the event in writing both to the faculty member, if possible, and unless prohibited by order of court, and to an Ombudsman, who shall be a member of the regular faculty selected annually by the Nominating Committee of the Faculty Senate and who has been endorsed by majority vote of the Faculty Senate. The Ombudsman shall be a current or retired regular faculty member who holds no administrative appointment and is not a member of the Faculty Review Committee. The Ombudsman shall have authority to investigate whether an intrusion was warranted by the policy and, (i) shall inform the President and the affected faculty member of the Ombudsman's findings; (ii) where a violation of the policy is found, shall inform the Faculty Review Committee of the policy violation; and (iii) where appropriate, in the absence of the affected faculty member, to bring a grievance before the Faculty Review Committee. Violation of any aspect of this policy is a sanctionable offense.

For purposes of this section, the term "faculty" shall mean any person who is a member of the Faculty Organization as defined in Article III of the Constitution of the Faculty Organization.

Access to Staff Data

Electronic data on a staff member's account, whether stored on a computer in the staff member's office or elsewhere under the proprietary control of that staff member, may not be examined, i.e., the contents of the data read by a person, without the staff member's consent, except in cases of emergency, in response to a valid subpoena, search warrant, order of a court, or by specific request by the staff members' supervisor for the purpose of accessing work-related electronic data. Posting of data by a staff member on servers available to the public or to members of the university shall be understood to imply consent, and electronic access given to specific parties by the staff member will likewise imply consent for those parties to access permitted data. Emergencies may include, for example, but are not limited to, the death, incapacity or disappearance of the staff member, or the search for and examination of files used for apparently malicious activity in an account which endangers the integrity of shared computers, the network, or other aspects of the university's computing infrastructure.

Only specifically designated individuals are permitted to determine what passes for an "emergency." Such individuals may be specifically designated, or may be designated by job position/description. All assignments for individuals or positions will be done by Provost or by a designate of the Provost.

Whenever possible and legally permissible, notification must be given to the staff member whose data are subject to subpoena, search warrant, or order of court prior to compliance therewith. Information obtained from an examination warranted by an emergency will not be released to the public, or to the university community or to public officials, except as such releases are essential to resolution of the emergency, or constitute evidence of a crime concealment of which would obstruct justice, and in the latter case release may only be to appropriate law enforcement officials. Any such findings may be reported to the staff member's supervisor, department head, or to Human Resources for appropriate investigation and action. Any intrusion by an employee of the University into a staff member's electronic data must be reported to the staff member as soon as possible, and within five days of the event via electronic mail unless prohibited by order of court, or due to a continuance of an ongoing investigation by the University. Violation of any aspect of this policy is a sanctionable offense.

When possible, staff members will be informed about the issuance of court orders, or other intrusions into their electronic data. In cases where a staff member believes that electronic data in their account has been inappropriately accessed by another staff member, the incident should be reported to Human Resources.

Access to Student Data

Electronic data stored in a student account, whether stored on a computer in the student's residence or elsewhere under the proprietary control of that student, may not be examined, i.e., the contents of the data read by a person, without the student's consent, except in cases of emergency or in response to a valid subpoena, search warrant, order of a court, or by order of the Office of the Dean of Student Affairs. Posting of data by a student on servers available to the public shall be understood to imply consent, and electronic access given to specific parties by the student will likewise imply consent for those parties to access permitted data. Emergencies may include, for example, but are not limited to, the death, incapacity or disappearance of the student, or the search for and examination of files used for apparently malicious activity in an account which endangers the integrity of shared computers, the network, or other aspects of the university's computing infrastructure.

Only specifically designated individuals are permitted to determine what passes for an "emergency". Such individuals may be specifically designated, or may be designated by job position/description. All assignments for individuals or positions will be done by Provost or by a designate of the Provost.

Whenever possible and legally permissible, notification must be given to the student whose data are subject to subpoena, search warrant, or order of court prior to compliance therewith. Information obtained from an examination warranted by an emergency will not be released to the public, or to the university community or to public officials, except as such releases are essential to resolution of the emergency, or constitute evidence of a crime of concealment which would obstruct justice, and in the latter case release may only be to appropriate law enforcement officials. Any findings of potential wrongdoing unrelated to the original intent of the search, must be reported to the Office of the Dean of Student Affairs for appropriate investigation and action. Any intrusion by an employee of the University into a student's electronic data must be reported to the student as soon as possible, and within five days of the event via electronic mail to the student, if possible, unless prohibited by an order of the court or because of an ongoing investigation conducted by the University. Violation of any aspect of this policy is a sanctionable offense.

When possible, students will be informed about the issuance of court orders, or other intrusions into their electronic data, including the purpose of the search. In cases where a student believes that electronic data in their account has been inappropriately accessed by a staff member, the incident should be reported to Office of the Dean of Student Affairs.

Note: Removable media such as floppy disks, zip drives, tapes, or CDs in a faculty or staff office, or in a residence hall are not subject to search by Computing Services, though Computing Services will assist authorized law enforcement agencies or authorities to read data after they are obtained, at the agencies' or authorities' request.

Protecting Confidential Information

Users who maintain confidential information, such as records relating to employees or students, are responsible for following privacy-related policies and laws.

Protecting Personal Information

As is described throughout this policy, data transmitted across the university network or stored on university systems may be accessed by others as a result of misuse by an individual, as an incidental result of the routine operation of the network and systems, or in response to a court subpoena or university investigation into suspected or alleged misuse. While complete privacy of personal data may not be possible, users who wish to ensure a higher degree of privacy for their data are encouraged to use encryption, PGP security, or other techniques to reduce the risk that others may access their data. For more information on these techniques, see various newsgroups (e.g. comp.security.pgp) or web references (e.g. comp.security.pgp FAQ).

Misuse and Inappropriate Behavior

The following activities are expressly prohibited at Carnegie Mellon:

- Using a computer system without proper authorization granted through the University, college, or department management structure. Some activities such as "port scanning" are not expressly prohibited. However, if the target of such scanning requests that an individual or system stop performing such actions, the person or system performing the scans must stop scanning the target machine unless the scans are being carried out by a system administrator who has the authority and responsibility over the machine(s) being scanned or for the network being used.
- Concealing your identity, or assuming the identity of another (e.g., by sending forged electronic mail). Note that some forms of electronic communication, such as browsing Web pages, passively "identify" users. Keeping your identity private either by not setting an identity in your browser or by using a Web-anonymizer in order to protect yourself from being put onto mailing lists is not a violation of this policy.
- Sharing your password or account with the specific exception of staff or faculty members allowing their support personnel to access their accounts in order to provide services appropriate to their job functions. Note that some policies for the accessing of specific systems or data (see Data and Computer Security, Confidentiality of Administrative Data) explicitly forbid the sharing of passwords used to access them, and that such restrictions for those specific systems override this policy.
- Using another person's computer account, userID, files, or data without appropriate permission, as described in the previous bullet (e.g. using an account found "logged in" on a cluster machine).
- Deleting or tampering with another user's files or with information stored by another user on any information-bearing medium (disk, tape, memory, etc.). Even if the user's files are unprotected, with the exception of files obviously intended for public reading, such as Web pages, it is improper for another user to read them unless the owner has given permission (e.g. in an announcement in class or on a computer bulletin board).
- Attempting to "crack" or guess other users' passwords. System administrators or those specifically designated by the administrator or owner of a system may attempt to crack passwords in order to test and enhance the security of the system. In cases where an individual or department "owns" machines which use password files controlled by another organization (e.g. Andrew machines or their like), the owner may not attempt to crack passwords without explicit permission by the owners of the password database.
- Obtaining passwords by other means, such as password capturing programs.
- Attempting to circumvent system security (e.g. breaking into a system or using programs to obtain "root" access), without the explicit permission of the owner of that system.
- Denying appropriate access to resources to other users (e.g. "ping flooding" another system, sending "mail bombs," or modifying a login file in order to cause a user to not be able to log in).
- Releasing programs such as viruses, Trojan horses, worms, etc., that disrupt other users, damage software or hardware, disrupt network performance, or replicate themselves for malicious purpose.
- Sending commercial solicitations via electronic mail (i.e. spamming) to individuals, or to newsgroups or mailing lists where such advertising is not part of the purpose of the group or list. (It is permissible to send a commercial solicitation to a "for sale" newsgroup, provided that the advertisement conforms to other policies and guidelines at Carnegie Mellon.)
- Any "mass mailing" which is solicitous in nature, unless the mailing is in the conduct of university business.
- Reselling of services based on the university network, such as web hosting, mailing services or the selling of shell accounts.
- Running a proxy server which results in inappropriate or unauthorized access to university materials to non-university members.
- Advertising commercial businesses or ventures on Web pages hosted by Carnegie Mellon, unless prior authorization has been granted.
- Using mail messages to harass or intimidate another person (such as by repeatedly sending unwanted mail or broadcasting unsolicited mail).
- Violations of any local, state or federal laws, such as the distribution of copyright-protected materials (e.g. the distribution of commercial software, music or films in electronic format without appropriate permissions by the owner, even if the user distributing the materials notifies others of their copyright status).
- Tampering with, willful destruction of or theft of any computer equipment, whether it belongs to the university or to an individual. Tampering includes any deliberate effort to degrade or halt a system, to tie up a system or to compromise the system/network performance. Willful destruction includes any deliberate disabling or damaging of computer systems, peripheral equipment such as scanners or printers, or other facilities or equipment including the network, and any deliberate destruction or impairment of software or other users' files or data.
- The unauthorized removal of university or another's computing equipment, which constitutes theft.

This list should not be considered to be complete or exhaustive. It should, however, serve as a set of examples of obviously inappropriate behaviors. If you are in doubt about the appropriateness of something that you want to do, contact the Computing Services Help Center at 8-HELP, or send mail to advisor+@andrew.cmu.edu and ask first.

Enforcement

Inappropriate behavior in the use of computers is punishable under the general university policies and regulations regarding faculty, students and staff. The offenses mentioned in this policy range from relatively minor to extremely serious, though even a minor offense may be treated severely if it is repeated or malicious. Certain offenses may also be subject to prosecution under federal, state or local laws.

Appropriate disciplinary action depends not only on the nature of the offense, but also on the intent and previous history of the offender. The range of possible penalties includes reprimands, loss of computing privileges, course failures for students, disciplinary probation, suspension or dismissal from the university and/or criminal prosecution.

Offenses that are minor or appear to be accidental in nature are often handled in a very informal manner such as through electronic mail. More serious offenses will involve formal procedures pursued through the Division of Student Affairs for students, Human Resources and/or the hiring university department or administrative unit for staff, or the Faculty Review Committee for faculty.

Restrictions of Privileges During Investigations

During the course of an investigation of alleged inappropriate or unauthorized use, it may be necessary to temporarily suspend a user's network or computing privileges, but only after determining there is at least a prima facie case against the individual, as well as a risk to the university or it's computing resources if privileges are not revoked. In these cases, it is important to recognize that the restriction of network or computing privileges is intended to protect the system rather than to punish the individual. For example, if a computer account has been used to launch an attack on another system, that account will be rendered inactive until the investigation is complete. This is a necessary action taken to prevent further misuse and does not presume that the account holder initiated the misuse. Unsubstantiated reports of abuse will not result in the suspension of accounts or network access unless sufficient evidence is provided to show that inappropriate activity occurred. For example, if someone reports that their computer was "attacked" by a Carnegie Mellon system, the burden will be upon the complainant to provide sufficient data logs or other evidence to show that the incident did, indeed at least appear to be an attack.

Adverse Impact on Shared Systems

The university reserves the right to discontinue communication with external systems that are known to harbor spammers or account crackers, despite the fact that this may restrict certain acceptable communications. When deemed necessary, this action will be taken to protect the security and safety of our systems. Similarly, there may be cases where a particular service or activity on a given University system will, by the very nature of its legitimate operation, tend to generate attacks from other Internet sites. If these attacks are frequent and severe enough to cause service interruptions for larger parts of the campus community, it may be necessary to temporarily or permanently remove these systems from the campus network. In cases where such an action is deemed necessary, network administrators will work with the maintainers of the system to identify alternative methods of network access. In cases where the university restricts access to external sites or removes network access for internal sites, the purpose of the action is to maintain the security and reliability of the computer systems and networks rather than to punish an individual or a site, or to restrict the free expression of ideas.

Discriminatory and Sexual Misconduct Policy (Interim)

https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/index.html (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/)

I. Policy Statement

The mission of Carnegie Mellon University is to cultivate a transformative educational experience for its Students that is committed to promoting and safeguarding their personal health and well-being. In addition, the mission is to create a collaborative environment open to the free exchange of ideas, where research, creativity, innovation, and entrepreneurship can flourish and where individuals can achieve their full potential. Consistent with the university's Statement of Assurance (https://www.cmu.edu/policies/administrative-and-governance/statement-of-assurance.html), it is the policy of Carnegie Mellon University to maintain an academic and work environment that promotes the confidence to work, study, innovate, and perform without fear of discriminatory and sexual misconduct. Such misconduct diminishes individual dignity, is contrary to the values of the university, and is a barrier to fulfilling the university's mission. It will not be tolerated at Carnegie Mellon University. This Policy contains grievance procedures that provide for the prompt and equitable resolution of Complaints alleging any action which would be prohibited by this Policy.

It is the responsibility of every member of the University community to foster an environment free of discriminatory and sexual misconduct. All members of the University community are encouraged to take reasonable and prudent actions to prevent or stop such behavior. In the event an Employee becomes aware of potential Prohibited Conduct, they should report the information to the Office for Institutional Equity and Title IX (the "IEX Office"). See Section III of this Policy for more information about making a Report of Prohibited Conduct.

The Policy prohibits the types of misconduct listed below and defined in Section VII.A (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/definitions.html#prohibited-conduct) (referred to collectively as "Prohibited Conduct"):

- Discrimination (including Disparate Treatment) (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/definitions.html#discrimination);
- Discriminatory Harassment (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/definitions.html#discriminatory-harassment);
- Sex Discrimination (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/definitions.html#discrimination)
- Sex-Based Harassment (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/definitions.html#sex-based-harassment), including
  - Quid Pro Quo Sex-Based Harassment,
  - Hostile Environment Sex-Based Harassment,
  - Sexual Assault,
  - Dating Violence,
  - Domestic Violence,
  - Stalking (based on sex), and
- Stalking (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/definitions.html#stalking)
- Retaliation (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/definitions.html#retaliation); and
- Violation of Protective Measures (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/definitions.html#violation).

This Policy is intended to: (1) prevent, eliminate, and remedy the effects of Prohibited Conduct; (2) foster an environment where all individuals are well-informed and supported in reporting Prohibited Conduct; and (3) provide an adequate, reliable, prompt, fair and impartial process for all parties once the university receives a Report of possible Prohibited Conduct. While these principles are clear and straightforward, the detailed procedures set forth in this Policy and related documents are necessary to assure that these matters are handled in an impartial, thoughtful, and thorough manner, consistent with the university's dedication to the integrity of its process.

Employees (including Faculty and Staff), Students, or third parties who violate this Policy may face, as appropriate, responsive action up to and including termination, expulsion, or other actions.

Nothing in this Policy shall be construed to abridge the free expression of ideas that is essential to the university's mission. The discourse conducted in accordance with the university's Freedom of Expression Policy (https://www.cmu.edu/policies/administrative-and-governance/freedom-of-expression.html) and with the statement on Academic Freedom and Responsibility enunciated in the Appointment and Tenure Policy (https://www.cmu.edu/policies/faculty/appointment-and-tenure-policy.html), whether in written, spoken, or electronic forms, shall be consistent with this Policy.

This Policy is intended to meet the university's obligations under Title VI of the Civil Rights Act of 1964 ("Title VI"); Title VII of the Civil Rights Act of 1964 ("Title VII"); Title IX of the Education Amendments of 1972 ("Title IX"); the Jeanne Clery Disclosure of Campus Security Policy and Campus Crime Statistics Act ("Clery Act"), as amended by the Violence Against Women Reauthorization Act of 2013 ("VAWA"), with respect to its application to sexual misconduct; and other applicable law and regulations.

II. Jurisdiction

This Policy applies to Employees (including Faculty and Staff), Students, and third parties and to all conduct within the university's Programs or Activities, as defined below. However, the university will address conduct contributing to a Hostile Environment even if the underlying conduct itself occurred outside the university's Programs or Activities, including if it occurred outside the United States, and including conduct occurring online via computer and internet networks or on digital platforms, including social media sites.

The university retains discretion to determine whether conduct outside of its Programs and Activities is within its jurisdiction. In making this determination, the university will consider the severity of the alleged conduct, the risk of ongoing harm, whether both parties are members of the University community, impact on University Programs or Activities (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/definitions.html#university-programs), and whether the off-campus conduct is part of a series of actions that occurred both on and off campus.

Some forms of conduct which may be considered inappropriate or unacceptable within the University community, such as incivility or bullying, may not meet the definition of Prohibited Conduct under this Policy. However, the university retains discretion to report the conduct to an internal university department or authority such as Human Resources, Office of Community Responsibility, or relevant academic department or dean to determine and implement appropriate responsive action, including review for possible misconduct under other university policies.

This Policy does not apply to the implementation or appeal of requests for modifications or academic adjustments for individuals with disabilities. Concerns related to the implementation or appeal of requests for modifications or academic adjustments should be submitted to the Office of Disability Resources (https://www.cmu.edu/disability-resources/students/forms.html) (students) or HR Disability Services (https://www.cmu.edu/hr/work-life/accommodations/) (Faculty and Staff).[1] This Policy supersedes any conflicting information in any other university policies with respect to the definitions or procedures relating to Prohibited Conduct.

[1]Individuals with a Disability are entitled to reasonable accommodations that would enable them to participate in all processes provided for under this Policy, including, but not limited to, making a Report or Complaint, participating in an Alternative Resolution Process, and/or participating in an investigation and adjudication under the grievance procedures. If an individual requires such reasonable accommodations, they should promptly notify the IEX Office, which may consult, as appropriate, with the Office of Disability Resources or Human Resources; individuals should not assume that the IEX Office is on notice that they have a Disability, even if registered to receive accommodations via the Office of Disability Resources, Human Resources, or another academic or administrative unit.

III. Reporting

The university strives to create an environment where all members of the University community are aware of options for informing the university about instances of suspected Prohibited Conduct, how to seek assistance and support, and how to pursue university action for their own protection and that of the entire campus community. This Policy distinguishes the action of making a Report of possible Prohibited Conduct from filing a Complaint. Thus, information shared about suspected Prohibited Conduct does not automatically trigger the initiation of grievance procedures (investigation or adjudication), as discussed below in Section VI.A (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/complaint-resolved.html#a). This section outlines the mechanisms for making a Report and how the university will respond to information it receives.

A. How to Make a Report

Any individual, including Students, Employees (including Faculty and Staff), or third parties are encouraged to submit Reports of suspected Prohibited Conduct directly to the IEX Office (https://www.cmu.edu/title-ix/) in-person, via e-mail, phone call, or online.

- *To report in person:*
  - IEX Office/Title IX Coordinator
    4615 Forbes Avenue, Suite 330
    Pittsburgh, PA 15213
- *To report by phone or email:*
  - Please call (412) 268-7125 or
    email institutionalequity@andrew.cmu.edu
- *To report online:*
  - Please complete this Report Form (https://cmu.hracuity.net/webform/index/2e196578-4892-4aab-af10-72cc76b5b71f/) (not anonymous).
- *To report anonymously, online or by phone:*
  - Please go to cmu.ethicspoint.com (https://secure.ethicspoint.com/domain/media/en/gui/81082/) or call 844-587-0793.

The university maintains a Resource Guide (https://www.cmu.edu/title-ix/resources-and-information/sexual_misconduct.html) for individuals who file reports of Prohibited Conduct that provides information for community members about obtaining support from campus and/or community resources, filing reports of Prohibited Conduct through the university's policies, and how to support a friend or family member who has been impacted by such conduct. Individuals who report Prohibited Conduct in Pennsylvania will also be informed of their rights as a victim of a crime under Pennsylvania law (https://pcv.pccd.pa.gov/for-victims/Pages/Your-Rights-as-a-Victim.aspx).

Inquiries about the application of civil rights laws to the university or questions regarding this Policy may be directed to the IEX Office, and may also be directed externally to the United States Department of Education's Office for Civil Rights ("OCR"), contact for which follows.

Office for Civil Rights
U.S. Department of Education
400 Maryland Avenue, SW Washington, D.C. 20202-1100
Phone: (800) 421-3481
Fax: (202) 453-6012
TDD#: (877) 521-2172
Email: OCR@ed.gov
Web: https://www.ed.gov/ocr (https://www.ed.gov/ocr/)

B. Mandatory Employee Reporting

All Carnegie Mellon Employees are required to report information about potential violations of this Policy to the IEX Office or the Title IX Coordinator. Reports may be submitted by phone (412-268-7125), email (institutionalequity@andrew.cmu.edu), or in-person by visiting the IEX Office at 4615 Forbes Ave., Pittsburgh, PA 15213. In addition, all teaching assistants are required to report information about potential violations of this Policy that is received within the student's role as a teaching assistant.

Sharing information with the IEX Office does not automatically trigger the university to initiate a Complaint or impose any obligations on the Complainant. However, disclosing information to the IEX Office enables the university to offer Supportive Measures to the parties so that they may maintain equal access to their education and work environments. As detailed in Section VI.A (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/complaint-resolved.html#a), in some circumstances, the IEX Office may initiate a Complaint based on the information received.
Upon receipt of a Report, the university will promptly contact the Complainant to discuss appropriate Supportive Measures (see Section V.A (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/respond-report.html#a)) and to explain the process for filing a Complaint (see Section VI.A (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/complaint-resolved.html#a)). Complainants are not obligated to respond to outreach from the university and the university will respect this decision, with limited exceptions where it is obligated by law or to act in the safety interest of the community.

With respect to Students who are also Employees, whether the individual is a mandatory reporter depends on the context in which the person learns of the alleged Prohibited Conduct. Mandatory reporter responsibilities are triggered if the person learned of the alleged Prohibited Conduct in the context of an Employee role, when they would, in that role, be considered a mandatory reporter. Mandatory reporter responsibilities are not triggered if the person learned of the alleged Prohibited Conduct in the context of their receipt of an education as a Student at Carnegie Mellon. However, student workers employed as a Resident Assistant or as a Community Advisor are required to report all potential violations of this Policy, regardless of whether such information is received in the course of the student worker's employment or as a student.

Public Awareness Events

Employees are required to report information disclosed at sexual misconduct public awareness events (e.g., Take Back the Night, candlelight vigils, protests, or survivor speak-outs in which participants may disclose incidents of Prohibited Conduct). However, disclosures at such events will not prompt the university to take responsive action unless the information reveals an immediate and serious threat to the health or safety of a Complainant, any Students, Employees, or other persons, or unless the individual affected by the alleged Prohibited Conduct clearly indicates that they desire responsive action be taken. The university will still use the information disclosed to inform its education and prevention efforts.

Classroom Disclosures

Disclosures of alleged Prohibited Conduct which occur in connection with a class or other academic setting are not exempt from reporting and such disclosures must be reported to the Title IX Coordinator as described above.

Exceptions to Mandatory Reporting:

Confidential Employees (see Section IV, below) are not required to make a Report when a person informs them of conduct that may constitute Prohibited Conduct if that information is provided while the Confidential Employee is functioning within the scope of their duties to which confidentiality applies.

Importantly, Confidential Employees must provide individuals who have disclosed potential Prohibited Conduct, upon receipt of such information:,

- Explain that they are a Confidential Employee;
- Provide contact information for the IEX Office;
- Explain how to report Prohibited Conduct; and
- Inform the disclosing individual that the IEX Office may be able to offer and coordinate Supportive Measures, as well as initiate an Alternative Resolution Process or investigation under the Grievance Procedures.

If you are unsure of whether you are required to report information, please contact the IEX Office in order to help clarify your responsibilities.

C. Anonymous Reporting

Any individual may make a report of Prohibited Conduct to the IEX Office, and if preferred, may do so without disclosing one's name using the online reporting portal, available online and by phone, listed above and here:

cmu.ethicspoint.com (https://secure.ethicspoint.com/domain/media/en/gui/81082/)
844-587-0793

Depending on the level of information available about the incident or the individuals involved, the university's ability to respond to an anonymous report may be limited. The university will, however, take whatever steps it deems appropriate and in the best interests of the overall University community, consistent with the information available. The university will never refuse to respond to a report solely on the grounds that it was made anonymously.

Information collected through the anonymous reporting line will be shared only with necessary university officials in order to respond to the reported concern. Information is kept confidential and no personally identifiable information is shared, except as necessary to follow this Policy, without the party's consent.

Filing an anonymous report does not satisfy the mandatory reporting obligations of Employees under Section III.B.

D. Reports to Law Enforcement

An individual who experiences, witnesses, or learns of possible criminal conduct may contact law enforcement directly by calling:

- 911 (for emergencies off-campus)
- University Police Department
  300 South Craig Street
  Pittsburgh, PA 15213
  (412) 268-2323 (for emergencies on-campus)
  campuspd@andrew.cmu.edu

Making a report to law enforcement does not generally obligate an individual to pursue a criminal complaint, or to participate in the university's disciplinary process. An individual may choose to participate in the university's disciplinary process, an external criminal process, both, or neither. In the event that both criminal and disciplinary processes are at issue, the university may comply with law enforcement requests for temporary delays in the disciplinary process in order to permit law enforcement to gather evidence for a criminal investigation.

Information about local medical care, local hospitals, including where a person may obtain an examination by a Sexual Assault Nurse Examiner (SANE) is available on the website for IEX Office (https://www.cmu.edu/title-ix/resources-and-information/).

Medical care may address physical and mental health concerns, including, where applicable, those related to pregnancy and/or sexually transmitted infections. Medical providers may also be able to assist in the collection and preservation of evidence. The ability to collect and preserve evidence of Sexual Assault is limited in time, so it is essential that care be sought as soon as possible. Individuals should avoid showering/bathing, douching, and, if possible, urinating. In the event of oral sexual contact, individuals should avoid eating, drinking, or brushing teeth. Any soiled clothes, towels, or bedding should be retained in paper bags. Preserving physical evidence in this manner may facilitate a criminal investigation, but seeking medical treatment does not obligate an individual to pursue a criminal complaint.

E. How the Office for Institutional Equity and University Police Share Information about Prohibited Conduct

The university's process for addressing Prohibited Conduct is separate from the law enforcement process for addressing crimes.

The university strongly believes that the decision as to whether to report a crime should be left to the individual(s) impacted by the crime, except in very limited circumstances where there may be an immediate threat to the University community or other legal obligation to report. The IEX Office will share de-identified information about Reports with University Police where required for the purpose of complying with the university's federal reporting obligations to facilitate accurate compilation of crime statistics, and to ensure that other public safety responsibilities are addressed. In extremely limited circumstances, the IEX Office may share identifying information with University Police, for example, where the university is obligated to report a "Timely Warning" pursuant to Jeanne Clery Disclosure of Campus Security Policy and Campus Crime Statistics Act (e.g., when a crime has been committed on or near University Property which represents a serious, ongoing threat and/or is part of an ongoing pattern). The report does not constitute a criminal complaint to law enforcement, although the University Police Department may contact individuals to offer assistance, inquire about their willingness to preserve evidence, or file a criminal complaint.

Making a report to the University Police means that information will be shared with others as is necessary and appropriate. For example, if an individual makes a report of Prohibited Conduct to the University Police Department that has not already been reported to the IEX Office, the University Police Department will report the matter to the IEX Office. The purpose of this report is to ensure that the university can take appropriate actions to seek to eliminate Prohibited Conduct, prevent its recurrence, and remedy its effects. The Complainant or others may be contacted by the IEX Office to follow up on the information received from the University Police Department to offer supportive measures, including filing a Complaint with the IEX Office (https://www.cmu.edu/title-ix/).

F. Annual Training

As required by applicable Title IX regulations, the university must ensure that all university Employees receive training related to their duties under Title IX promptly upon hiring or change of position that alters their duties under Title IX and annually thereafter.

All Employees must be annually trained on:

1. The obligation to address Sex Discrimination in University Programs or Activities and how to report Prohibited Conduct to the IEX Office;
2. The scope of conduct that constitutes Sex Discrimination, Sex-Based Harassment, and related Retaliation under this Policy; and
3. All applicable notification and information requirements, including the Employee's mandatory reporting obligation with respect to known or suspected Sex Discrimination, and the Employee's duty to provide certain required disclosures to a Student, as discussed further below, when informed by a Student of that Student's Pregnancy or related conditions.

Additional training on specific topics is required of investigators, decisionmakers, and other persons who are responsible for implementing the university's grievance procedures or have the authority to modify or terminate Supportive Measures; facilitators of any Alternative Resolution Process; and the university's Title IX Coordinator and designees. Additional information regarding training is available on the IEX website (https://www.cmu.edu/title-ix/education-and-training/).

G. Amnesty for Students When Reporting Prohibited Conduct to the University

The university will not pursue violations of the university's Alcohol and Drug Policy (https://www.cmu.edu/policies/administrative-and-governance/alcohol-and-drug-policy.html) and/or Hazing Policy (https://www.cmu.edu/student-affairs/theword/community-policies/hazing.html) against any Student in an investigation under this Policy for potential violations of the Alcohol and Drug Policy (https://www.cmu.edu/policies/administrative-and-governance/alcohol-and-drug-policy.html) and/or Hazing Policy (https://www.cmu.edu/student-affairs/theword/community-policies/hazing.html), as long as any such violations did not and do not place the health or safety of any other person at risk. The university may, however, initiate an assessment, educational discussion, or pursue other developmental interventions (non-disciplinary options) to address hazing or the use of alcohol or other drug use.

V. Confidential Resources and Privacy

Carnegie Mellon understands that some individuals impacted by Prohibited Conduct, particularly conduct involving sexual violence, may not be ready or may not be willing to report through a channel that may lead to an investigation or other university action, no matter how discreet. For such individuals, several confidential resources are available both on and off campus.

A. Confidential University Employees

The following university Employees are designated as Confidential Employees who are able to confidentially receive and discuss information related to alleged Prohibited Conduct.[1]

- Employees in Counseling and Psychological Services (CaPS);
- Employees in University Health Services (UHS);
- Religious and Spiritual Life Coordinator;
- The Student and Faculty Ombudsperson;
- The Staff Ombudsperson; and
- Employees who conduct human subjects-research studies that have been approved by the Institutional Review Board (IRB) and which are designed to gather information about Sex Discrimination, with respect to information disclosed in the course of conducting the approved study;

In order for confidentiality to apply, Confidential Employees must be functioning within the scope of the Employee's job duties to which confidentiality applies. Confidentiality does not apply if the Employee receives information outside the scope of such job duties.

Although Confidential Employees are exempt from mandatory reporting, as required by law, Confidential Employees must provide the following information to any person who informs the Confidential Employee of conduct that reasonably may constitute Sex Discrimination or other Prohibited Conduct under this Policy:

1. That they are a Confidential Employee;
2. How to contact the Title IX Coordinator;
3. How to make a Complaint of Prohibited Conduct; and
4. That the IEX Office and Title IX Coordinator may be able to offer and coordinate Supportive Measures, as well as initiate an Alternative Resolution Process or investigation under the Grievance Procedures.

Confidential Employees can provide individuals with assistance, support, and additional information. Confidential Employees are prohibited from disclosing confidential information unless (1) given permission by the person who disclosed the information; (2) there is an imminent threat of harm to self or others; (3) the conduct involves suspected abuse of a minor under the age of 18; or (4) as otherwise required or permitted by law or court order. Confidential Employees may be required to report non- identifying information to University Police Department for crime reporting purposes.

Contact information for Campus Confidential Employees:

- Counseling and Psychological Services (https://www.cmu.edu/counseling/) (CaPS) (Student only)
  412-268-2922
- University Health Services (https://www.cmu.edu/health-services/) (Student only)
  412-268-2157
- University Health Services - Health Promotions Team (Student only)
- Staff Ombudsperson (https://www.cmu.edu/hr/resources/ombudsperson/)
  412-268-1018
- Student and Faculty Ombudsperson
- Religious and Spiritual Life Coordinator;
  412-268-3559

In addition, Carnegie Mellon employees may seek confidential assistance through the Employee Assistance Program (https://www.cmu.edu/hr/work-life/support/eap/) (CMU Employees only).

B. External Community Resources

Individuals may also seek assistance and support from a variety of external resources, including those listed below. These resources are available free of charge to students, undergraduate and graduate, faculty and staff, regardless of whether a person lives in campus housing and regardless of an individual's sex, gender, or sexual orientation. Individuals may contact the resources directly or the university can assist individuals with connections by request.

- Women's Shelter and Center of Greater Pittsburgh (https://wcspittsburgh.org/)
- Pittsburgh Action Against Rape (https://paar.net/)
- Center for Victims (https://www.centerforvictims.org/)
- Persad (https://www.persadcenter.org/)

C. Privacy

Although often conflated, privacy and confidentiality are distinct terms with distinct meanings. Privacy refers to the university's commitment to sharing information related to any Report, Complaint, Supportive Measures, Alternative Resolution Process, or grievance procedures under this Policy only:

- To a person with a legal right to receive disclosures of information, or with prior written consent;
- When necessary to effectuate this Policy, or to otherwise address conduct which may reasonably constitute Prohibited Conduct;
- As required by Federal law or regulation, including by the terms and conditions of a Federal award (e.g., a grant award or other funding agreement); and/or
- When required or permitted by State or local law or the Family Educational Rights and Privacy Act ("FERPA"). See the university's Policy on Student Privacy Rights (https://www.cmu.edu/policies/student-and-student-life/privacy-rights-students.html) for more information about FERPA.

The university provides training to personnel regarding the safeguarding of private information, instructs parties and witnesses about the university's privacy-related expectations, and will take other reasonable steps to prevent and address the parties' and, if applicable, their Advisors', unauthorized disclosure of information and evidence obtained solely through the grievance procedures.

In any grievance process, other than as provided for in this Policy, the university will not restrict the ability of either party to discuss the allegations prompting a Report or Complaint, including for the purposes of obtaining and presenting evidence (such as by speaking to witnesses), consulting with family members, confidential resources, or advisors, or otherwise preparing for or participating in the grievance procedures.

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[1]This section address confidentiality with respect to reports under this Policy. This section does not affect any other legal privileges, such as physician-patient or counselor-client privileges. Only certain licensed treatment providers in UHS and CaPS have physician-patient or counselor-client privilege. Please contact UHS or CaPS for more information about these privileges.

V. How the University Responds to Reports

A. Supportive Measures

The university is committed to helping Complainants and Respondents continue their education and employment after a report of alleged Prohibited Conduct. Regardless of whether Complainant chooses to pursue an Alternative Resolution Process, grievance procedures, or no further process, the Title IX Coordinator or a designated university official conducts an initial assessment to determine next steps and will initiate contact the Complainant to discuss the availability of Supportive Measures. Respondents will also be offered supportive measures after receiving a Notice of Allegation.

Supportive Measures are non-disciplinary, non-punitive individualized services, assistance, and other measures that the university offers and may put in place, without fee or charge, as appropriate and available, after receiving a Report of possible Prohibited Conduct. Supportive Measures are designed to restore or preserve access to the University's Programs and Activities, or provide support during the grievance process or during the Alternative Resolution Process. Supportive Measures cannot be unreasonably burdensome to a party.

Supportive Measures are available before and after a Complaint is filed, and in cases in which no Complaint is filed.

Upon receipt of a Report, the Title IX Coordinator, or their designee, will contact the Complainant (1) to discuss the availability of Supportive Measures and (2) to explain that Supportive Measures are available with or without the filing of a Complaint. The Title IX Case Manager helps determine the appropriate Supportive Measure(s) to be implemented. The Title IX Case Manager will assess with the relevant party the unique facts and circumstances of their situation and identify steps to help the individual meet their educational or employment expectations.

Supportive Measures may be modified or terminated at the conclusion of a grievance process or Alternative Resolution Process.

Examples of Supportive Measures include, but are not limited to:

- Academic support services and accommodations, including the ability to reschedule classes, exams and assignments, transfer course sections, or withdraw from courses;
- Academic schedule modifications (typically to separate Complainant and Respondent);
- Work schedule or job assignment modifications (for university employment);
- Changes in on-campus work or university housing location;
- On-campus counseling services and/or assistance in connecting to community-based counseling services;
- Assistance in connecting to community-based medical services;
- No contact agreements or orders, which may be mutual or non-mutual;
- Temporarily limiting an individual's access to certain university facilities or activities;
- Information about and/or assistance with obtaining personal protection orders;
- Leaves of absences;
- Increased monitoring and security of certain areas of the campus;
- Options for emergency Housing;
- Individualized limitations on the parties' communications and interactions with each other; or
- A combination of any of these measures.

Changes in class, work, housing, extracurricular, and/or other activities may be made regardless of whether there is or is not a comparable alternative.

The university will maintain Supportive Measures provided to the Complainant or Respondent as confidential to the extent that maintaining such confidentiality would not impair the university's ability to provide the Supportive Measures or restore or preserve a party's access to university's Programs or Activities.

B. Appeals and Modifications of Supportive Measures

Complainants and Respondents may seek modification or reversal of a decision related to the creation, denial, modification, or termination of a Supportive Measure. If a party's condition materially changes, the individual may seek additional modification or termination of a Supportive Measure applicable to them. Requests for the appeal, modification, or termination of Supportive Measures must be submitted in writing to the IEX Office via email to institutionalequity@andrew.cmu.edu. The decisionmaker on the appeal will be someone other than the person who made the decision being challenged, and who will have the authority to make the requested modification or reversal.

VI. How a Complaint is Resolved

A. Initiating a Complaint

A Complaint may be filed with the IEX Office orally in person, by mail, or by email. Complainants are strongly encouraged, but not required, to submit a Complaint Form [pdf] (https://www.cmu.edu/title-ix/tix-formal-complaint-form_2022.pdf). A Complainant may file a Complaint at any time, but significant delays between the time an incident occurs and conducting an investigation may impede or limit the availability of Relevant evidence and/or availability of witnesses.

Upon the filing of a Complaint, the IEX Office will contact the Complainant to confirm receipt of the Complaint and to confirm the allegations as understood by the IEX Office. Before initiating the grievance procedures, the IEX Office will review the Complaint to determine whether there is any basis to dismiss the Complaint, as detailed in Section VI.B below. Otherwise, the IEX Office will initiate the grievance procedures and commence an investigation as detailed in Section VI.C below. The Complainant may also wish to pursue the Alternative Resolution Process, an alternative track discussed further below, instead of or after filing a Complaint.

In certain circumstances, the IEX Office may file a Complaint and initiate an investigation in the absence of an identifiable Complainant or when a Complainant is unwilling to proceed with a Complaint. In making the determination to initiate a Complaint, the IEX Office must consider, at a minimum, the following factors:

1. The Complainant's request not to proceed with the initiation of a Complaint;
2. The Complainant's reasonable safety concerns regarding the initiation of a Complaint;
3. The risk that additional acts of Prohibited Conduct would occur if a Complaint is not initiated;
4. The severity of the alleged Prohibited Conduct, including whether the alleged misconduct, if established, would require the removal of a Respondent from the university's campus or imposition of another Disciplinary Sanction to end the Prohibited Conduct and prevent its recurrence;
5. The age and relationship of the parties, including whether the Respondent is an Employee of the university;
6. The scope of the alleged Prohibited Conduct, including information suggesting a pattern, ongoing Prohibited Conduct, and/or Prohibited Conduct alleged to have impacted multiple individuals;
7. The availability of evidence to assist the Hearing Officer or other decisionmakers in determining whether Prohibited Conduct occurred; and
8. Whether the university could end the alleged Prohibited Conduct and prevent its recurrence without initiating a Complaint.

After considering the above factors and any other relevant factors, if the IEX Office determines that the conduct as alleged presents an imminent and serious threat to the health or safety of the Complainant or another person, or that the conduct as alleged prevents the university from ensuring equal access on the base of any Protected Class to the University's Programs or Activities, the IEX Office may initiate a Complaint and commence an investigation.

If the IEX Office decides to initiate a Complaint, the IEX Office will notify the Complainant (if identifiable) prior to the initiation of the Complaint in order to address any reasonable safety concerns, including via options for Supportive Measures under Section V.A (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/respond-report.html#a). Regardless of whether a Complaint is initiated, the IEX Office will take other appropriate prompt and effective steps necessary to ensure the Prohibited Conduct does not continue or recur within the University's Programs or Activities.

The IEX Office may consolidate complaints of Prohibited Conduct against more than one Respondent, or by more than one Complainant against one or more Respondents, or by one party against another party ("cross complaints"), when the allegations of Prohibited Conduct arise out of the same alleged facts or circumstances. When the university receives a report of alleged conduct that could constitute Prohibited Conduct under this Policy and could also violate other university policies, the university, in its discretion, will determine which policy/ies and procedures apply and whether action will be taken under multiple policies.

Both the Complainant and the Respondent may select an Advisor of their choice. Details concerning the role of the Advisor are set forth in the applicable adjudication procedures under Section VI.D.

The Respondent is presumed to be Not Responsible for any alleged Prohibited Conduct until a determination is made at the conclusion of the adjudication procedures set forth in this Policy.

The university will not discipline a party, witness, or others who participate in the investigation or adjudication of a Complaint for making a false statement or for engaging in consensual sexual conduct based solely on the determination of responsibility for Prohibited Conduct under this Policy. Allegations that an individual has provided a false statement must be separately reviewed under applicable university policy (e.g., *The Word*, the Staff Handbook, or the Code of Business Ethics) and such allegations, in general, will be stayed until the completion of the underlying proceedings in this Policy. Allegations of a violation of the Consensual and Intimate Relationship Policy Regarding Undergraduate Students (https://www.cmu.edu/policies/student-and-student-life/consensual-relationships.html) must be separately reviewed under that policy.

The IEX Office will establish and maintain on its website reasonably prompt time frames (https://www.cmu.edu/title-ix/university-response/discriminatory-and-sexual-misconduct-investigation-and-resolution-process.html) for the major stages of the Complaint process. These timeframes may be extended on a case-by-case basis for good cause. When such timeframes are extended, the IEX Office will provide written notice of the reason for delay to the Complainant and Respondent.

For any allegation of Prohibited Conduct that allegedly occurred before the effective date of this Policy, the university will use the applicable policy that was in effect at the time the Prohibited Conduct allegedly occurred for the purpose of defining conduct that constitutes a violation of policy. However, the matter will be investigated and adjudicated using the current procedures as set forth in this Section VI of this Policy. Complaints filed before the effective date of this Policy and that were still pending as of such effective date will be completed using the policy in effect when the Formal Complaint was filed.

B. Dismissal and Withdrawal of a Complaint

At any time during the pendency of a Complaint, the IEX Office may dismiss the Complaint on any of the following bases:

1. The university is unable to identify the Respondent after taking reasonable steps to do so;
2. The Respondent is not or is no longer a Student or Employee of the university and is not otherwise participating in the University's Programs or Activities;
3. The Complainant voluntarily requests to withdraw any/all allegations in writing and the IEX Office declines to initiate/continue the Complaint/grievance procedures, as described further below, and/or without the Complainant's withdrawn allegations, the conduct that remains alleged in the Complaint, if any, would not constitute Prohibited Conduct even if established); or
4. The IEX Office determines that even if proven, the alleged conduct would not constitute Prohibited Conduct.

Upon dismissal of a Complaint, the IEX Office will provide prompt written notice to the Complainant of the basis for the dismissal and the right to appeal the dismissal decision under Section VI.F. If the dismissal occurs after the Respondent has been issued a Notice of Allegations, the IEX Office will also provide such written notice to the Respondent.

If a Complaint is dismissed before the IEX Office has issued a Notice of Allegations to the Respondent, only the Complainant will have the opportunity to appeal the decision to dismiss the Complainant. If the Complaint is dismissed after the IEX Office issued a Notice of Allegations to the Respondent, the Complainant and Respondent will have an equal opportunity to appeal the dismissal decision.

A Complainant who filed a Complaint may request withdrawal of such complaint at any time by submitting a written request to the Investigator assigned to the case or the IEX Office. After a Complainant requests withdrawal of a Complaint, the IEX Office will review the matter, considering the same factors as specified in Section VI.A, to determine whether to grant the request for withdrawal or to continue the Complaint. If the IEX Office refuses a request by a Complainant to dismiss a Complaint, the Complainant will be notified in writing of the decision and rationale.

C. Investigation Procedures

After deciding to commence an investigation, the Title IX Coordinator will appoint an investigator to review, assess, and investigate the Complaint (the "Investigator"). The Investigator may be a staff member in the IEX Office, a staff member in Human Resources, a staff member in another department at the university, or an external professional. The Title IX Coordinator is responsible for ensuring that the Investigator has been appropriately trained and is free of conflicts of interest or bias — for or against Complainants or Respondents generally, or a specific Complainant or Respondent — that would impair the investigation. If a party has concerns about bias in favor of or against a specific Complainant or Respondent, bias in favor of or against Complainants or Respondents generally, or a potential conflict of interest which involves the Title IX Coordinator, facilitator of an Alternative Resolution Process, investigator, decisionmaker, or appeals decisionmaker, the party should direct those concerns to the Title IX Coordinator. Concerns regarding bias or conflict of interest on the part of the Title IX Coordinator will be referred to the Vice Provost for Diversity, Equity and Inclusion and Chief Diversity Officer (or designee) for review.

The IEX Office will send the Complainant and Respondent a written Notice of Allegations. If in the course of an investigation, the IEX Office decides to investigate additional allegations of Prohibited Conduct not included within the original notice or if it is necessary to make revisions to the allegations, the IEX Office will issue an amended Notice of Allegations to the Complainant and Respondent. The issuance of a Notice of Allegations may be reasonably delayed as necessary to address any reasonable concerns for the safety of any person as a result of providing such notice.

The Notice of Allegations will include:

- information about the Alternative Resolution Process and grievance procedures;
- the identities of the parties involved in the incident(s), the conduct alleged to constitute Prohibited Conduct, and the date(s) and location(s) of the alleged incident(s), if known;
- information about the university's prohibition on Retaliation;
- a statement that the parties are entitled to an investigative report summarizing all Relevant evidence and retain the equal right to access such evidence upon request;
- a statement that the Respondent is presumed not responsible for the alleged Prohibited Conduct until a determination is made at the conclusion of the grievance procedures, after the parties have had an opportunity to present Relevant (not otherwise impermissible) evidence to a trained, impartial decisionmaker;
- notice that the Parties have the right to be accompanied by an Advisor of choice, who may be but need not be an attorney;
- notice that knowingly making false statements or submitting false information is prohibited;
- information about Supportive Measures;
- a statement regarding the standard of proof to be used in considering the facts and evidence;
- the range of possible Disciplinary Sanctions and Remedies; and
- information about the appeals process.

The Investigator will conduct an investigation and prepare a preliminary investigative report that fairly summarizes the Relevant evidence gathered during the investigation. The Investigator will, prior to any interviews or meetings with the parties, provide written notice of the date, time, location, and purpose of the interview or meeting, with sufficient time for the party to prepare for the interview or meeting.

Prior to preparing any report, the Investigator will request Relevant information from the parties as well as work to gather other Relevant available evidence. The ultimate responsibility for gathering available Relevant evidence rests with the university. Throughout the investigation, the university will provide both parties equal opportunity for the parties to present witnesses, including fact and expert witnesses, and other inculpatory and exculpatory evidence. The parties may offer testimony from an expert witness, as specified in Appendix B (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/appendix-b.html) to this Policy.

The preliminary investigative report will be made available to the Complainant, Respondent, and their respective Advisors in electronic or hard-copy format. Any Relevant evidence collected during the investigation will also be made available to the Complainant, Respondent, and their respective Advisors for inspection and review in electronic or hard-copy format. The Complainant and Respondent will have at least seven (7) calendar days to review and respond to the preliminary investigative report. The Investigator will consider any responses submitted by the Complainant, Respondent and their respective Advisors and prepare a final investigative report ("Investigative Report").

D. Adjudication Procedures

The specific procedures for adjudicating allegations of Prohibited Conduct are based upon the nature of the parties' relationship to the university.

1. Where the Complainant or Respondent is a Student — the matter will be handled in accordance with the Hearing Procedures set forth in Section VI.E and the Appeal Procedures set forth in Section VI.F. This subsection supersedes and controls over all other provisions of this Section VI.D.

   When a Complainant or Respondent is both a Student and an Employee (a "Student Employee"), the university will undertake a fact- and circumstance-specific inquiry to determine how the matter will be adjudicated, including consideration of whether the party's primary relationship with the university is to receive an education, and whether the alleged Prohibited Conduct occurred while the party was performing employment-related work. Typically, if a Respondent who is a Student Employee may experience a change in their employment status as a result of the outcome of a grievance process, but not a change in their student status, the matter will proceed as though the Respondent was a Staff member.
2. Where the Respondent is a Faculty member — the matter will be handled in accordance with the Hearing Procedures set forth in Section VI.E and the Appeal Procedures set forth in Section VI.F.

3. Where the Respondent is a Staff member — the IEX Office will send the Investigative Report to the Assistant Vice President of Human Resources, People and Organization Effectiveness, in Human Resources and the matter will be handled in accordance with the procedures set forth in the Staff Handbook (https://www.cmu.edu/hr/resources/policies/staff-handbook.html), Volume II, Section 10c. The Assistant Vice President of Human Resources, People & Organizational Effectiveness also has discretion to refer the matter for live hearing using the Hearing Procedures set forth in Section VI.E and the Appeal Procedures set forth in Section VI.F.
4. Where the Respondent is a Participant in a Summer Program:
    a. For cases involving allegations of Sex-Based Harassment or if the Complainant or Respondent is deemed to be a Student, the matter will be handled in accordance with the Hearing Procedures set forth in Section VI.E and the Appeal Procedures set forth in Section VI.F.
    b. For other allegations under this Policy, the matter will be handled in accordance with the Summer Programs Code of Conduct.
5. Where the Respondent is an on-going affiliate of the university who is not a Faculty member, Staff member, Student, or Participant in a Summer Program:
    a. For allegations of Sex Discrimination or Sex-Based Harassment, the IEX Office will appoint an Investigator to conduct an investigation in accordance with Section VI.C. After the completion of the Investigation, the Title IX Coordinator has discretion to either:
        i. Instruct the Investigator to make a determination of responsibility for each allegation in the Formal Complaint using the preponderance of the evidence standard. In conducting this review, the Investigator will follow the Procedures for Adjudication without a Live Hearing [pdf] (https://www.cmu.edu/policies/forms-and-documents/adjudication-procedures.pdf). Based on the Investigator's findings of responsibility, the Investigator will coordinate with the Title IX Coordinator and other university officials as necessary to determine appropriate Disciplinary Sanctions and/or Remedies. Appeals will be handled via the procedures set forth in Section VI.F; or
        ii. Refer the matter for live hearing in accordance with the Hearing Procedures set forth in Section VI.E and the Appeal Procedures set forth in Section VI.F
    b. For allegations of Prohibited Conduct that do not constitute Sex Discrimination or Sex-Based Harassment, the IEX Office will determine the appropriate manner of resolution in accordance with the university's commitment to a prompt and equitable process and consistent with any applicable state and federal law and regulations.

E. Live Hearing Procedures

The following procedures apply to live hearings held under this Policy, as indicated in Section VI.D.

Appointment of Hearing Officer

After reviewing the Investigative Report prepared under Section VI.C, the IEX Office will appoint a hearing officer ("Hearing Officer") who will be responsible for conducting a review of the case, presiding over a live hearing if necessary, and making findings of fact and a determination of responsibility with respect to each allegation in the Complaint.

Conduct of the Hearing & Written Determination

The Hearing Officer will conduct a live hearing in accordance with the Hearing Procedures for the Adjudication of Discriminatory and Sexual Misconduct [pdf] (https://www.cmu.edu/policies/forms-and-documents/hearing-procedures.pdf) ("Hearing Procedures"). The hearing will take place no sooner than ten (10) days after the parties are provided with the Investigative Report.

At the conclusion of the hearing, the Hearing Officer will objectively evaluate all Relevant evidence, both inculpatory and exculpatory, and make findings of fact and a determination of responsibility with respect to each allegation. The determination of responsibility will be made using the preponderance of evidence standard.

If the Hearing Officer determines that the Respondent is responsible for any allegation, the Hearing Officer will contact the appropriate sanctioning officer, as specified below, to review the findings of fact and determination(s) regarding responsibility ("Sanctioning Officer"). The Sanctioning Officer will have sole responsibility for determining the appropriate Disciplinary Sanctions and any Remedies related to any finding of responsibility made by the Hearing Officer. The Sanctioning Officer will provide a written determination regarding Disciplinary Sanctions and/or Remedies to the Hearing Officer. If the Hearing Officer determines that the Respondent is not responsible for any of the allegations, the Sanctioning Officer will not be contacted. Where the appointed Hearing Officer is an Employee of the university, the same individual may be appointed to serve as both the Hearing Officer and Sanctioning Officer.

The applicable Sanctioning Officer is based on the nature of the Respondent's relationship to the university:

- Sanctioning Officer for Students: Associate Vice President of Student Affairs for Community Life or designee (in consultation with the Community Standards Review Board (https://www.cmu.edu/student-affairs/theword/community-standards/definitions.html))
- Sanctioning Officer for Staff: Assistant Vice President for Human Resources, People & Organizational Effectiveness or designee
- Sanctioning Officer for Faculty: Vice Provost for Faculty or designee

The Hearing Officer will prepare a written determination regarding the findings of fact and the determination regarding responsibility for each allegation, with rationale and appeals information. Where applicable, the written decision of the Sanctioning Officer regarding Disciplinary Sanctions and/or Remedies will be attached to or incorporated into the written determination prepared by the Hearing Officer.

Notice of Written Determination

The written determination will be provided to the IEX Office. Except as detailed below regarding cases involving Student-Respondents, the IEX Office is responsible for providing the Complainant and Respondent with a copy of the written determination. Both parties must be provided the written determination simultaneously.

For Cases Involving Student-Respondents — Depending on the nature of the category of alleged Prohibited Conduct, the right of the Complainant to receive notice of the outcome(s), as well as the right to appeal the outcome(s), is restricted by the Family Educational Rights and Privacy Act (FERPA).;

Consistent with FERPA and applicable Title IX regulations, in Student-Respondent cases the outcome(s) applicable to a Student-Respondent will be disclosed to the Complainant only for the following offenses under this Policy:

- Sex-Based Harassment (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/definitions.html#sex-based-harassment), including
    - Quid Pro Quo Sexual Harassment,
    - Hostile Environment Sexual Harassment,
    - Sexual Assault,
    - Dating Violence,
    - Domestic Violence,
    - Stalking (based on sex),
- Stalking (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/definitions.html#stalking)
- Sex Discrimination (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/definitions.html#discrimination); and/or
- Retaliation (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/definitions.html#retaliation) where the underlying protected activity is related to the exercise of rights related to and/or Complaints of Sex Discrimination, including Sex-Based Harassment.

Consequently, as required by FERPA, in Student-Respondent cases, the outcome(s) applicable to a Student-Respondent will not be disclosed and the Complainant cannot appeal such outcome(s) for the following offenses under this Policy:

- Violation of Protective Measures (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/definitions.html#violation);
- Discrimination (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/definitions.html#discrimination) and/or Discriminatory Harassment (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/definitions.html#discriminatory-harassment) on the basis of race, color, national origin, disability, age, religion, ancestry, family status, parental status, marital status, veteran status, and genetic information;[1] and
- Retaliation (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/definitions.html#retaliation) where the underlying protected activity is related to the exercise of rights related to and/or complaints of race, color, national origin, disability,

age, religion (including creed, ancestry and belief), veteran status, and genetic information.

For Student-Respondent cases, the IEX Office will provide the Student-Respondent with a complete copy of the written determination for all allegations. Where applicable, the IEX Office will coordinate with the Hearing Officer to edit or redact the written determination issued to the Complainant in order to remove information related to the outcome(s) of alleged offenses which the university is not permitted to disclose, per the list above. Regardless of the type of allegation, any outcomes that apply to the Complainant (e.g. Remedies) will be shared with the Complainant.

Additional Procedures for Disciplinary Sanctions Against Faculty Respondents

In the case of sanctions against a Faculty Respondent, the Disciplinary Sanctions determined by the Sanctioning Officer for Faculty will be provided to the President as recommended Disciplinary Sanctions. The President will take no action on the recommended Disciplinary Sanctions until either (i) the completion of any appeal filed by any party under Section VI.F or (ii) the deadline to file an appeal under Section VI.F passes without any appeal being filed. If an appeal is filed, the President or the President’s designee will render a decision on the appeal consistent with the procedures in Section VI.F. If any Disciplinary Sanctions remain after the completion of the appeal or where no appeal is filed by the appeal deadline, the President will thereafter render a decision based on both the recommendation of the Sanctioning Officer for Faculty as well as the underlying findings of fact and determination(s) of responsibility by the Hearing Officer (or Appeal Officer, if applicable). If the President decides to initiate the procedure for dismissal for cause or for the imposition of another Disciplinary Sanction against a Faculty Respondent, the matter will then follow the process set forth in the subsection "Procedure" of the section of the Appointment and Tenure Policy of Carnegie Mellon University (https://www.cmu.edu/policies/faculty/appointment-and-tenure-policy.html) titled, "Dismissal for Cause and Other Sanctions," but will be subject to the "Exceptions" provision of that subsection such that no Ad-Hoc Committee will be required.

F. Appeal Procedures

Except as specified in Section VI.E for Student-Respondent cases, both the Complainant and Respondent have the right to file an appeal regarding (i) the determination under Section VI.E or (ii) the dismissal of a Complaint under Section VI.B. An appeal must be submitted in writing to the Office of the President (with a copy to the IEX Office) within seven (7) calendar days of the official notification of the determination under Section VI.B or Section VI.E.

The written appeal request must state the basis for the appeal. The basis for an appeal will be limited to one or more of the following:

- Procedural irregularity that would change the outcome of the matter;
- New evidence that would change the outcome and that was not reasonably available when the determination regarding responsibility or dismissal was made;
- The Title IX Coordinator, Investigator(s), Hearing Officer, or Sanctioning Officer had a conflict of interest or bias for or against Complainants or Respondents generally or the individual Complainant or Respondent that would change the outcome of the matter; and
- The sanctions imposed are disproportionate to the finding of responsibility.

The President or the President’s designee will serve as the Appeal Officer. The Appeal Officer will inform the other party or parties that an appeal has been filed and provide such party or parties with a copy of the written appeal. The non-appealing party will have a reasonable, equal opportunity to submit a responsive written statement for consideration by the Appeal Officer.

The Appeal Officer will review the written appeal and any response and determine whether, in the judgment of the Appeal Officer, sufficient grounds exist for at least one basis of appeal. An appeal that does not meet at least one of the acceptable bases for appeal may be dismissed without further review.

Appeals will be decided by the Appeal Officer in a timely manner as circumstances warrant. While an appeal is under review, the Appeal Officer will update the Respondent(s) and Complainant(s) as necessary about the anticipated timeline.

The Appeal Officer has the authority to modify the decision as deemed appropriate for resolution of the matter being appealed, which could entail (i) sending the matter back to an Investigator, the Hearing Officer, or a new Hearing Officer, as necessary to remedy the error or (ii) a decrease or change to the nature of the sanction(s). The Appeal Officer may also remand the matter for a new process under Section VI.D.

The Appeal Officer will issue a written decision describing the result of the appeal and the rationale for the result. The Appeal Officer will provide the written decision simultaneously to both the Complainant and Respondent. The IEX Office will also receive a copy of the decision.

G. Possible Disciplinary Sanctions and Remedies from Adjudication

Possible outcomes from a violation of this Policy range from educational outcomes to separation from the university. A detailed list of the possible remedies and sanctions is available in Appendix A to this Policy (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/appendix-a.html).

H. Alternative Resolution Process

Sections VI.A through VI.G of this Policy describe procedures for the grievance procedures for Complaints of Prohibited Conduct. Separate from these grievance procedures, the university offers an Alternative Resolution Process which may be available on a voluntary basis to resolve a matter under this Policy.

Individuals interested in an Alternative Resolution Process should contact the IEX Office to discuss options. For information regarding the types of Alternative Resolution Process that may be available please see the IEX Office website on Alternative Resolutions (https://www.cmu.edu/title-ix/how-to-report-+-options-for-resolution/alternative-resolution-options.html).

Either party may request to pursue an Alternative Resolution Process at any time before a finding of responsibility resulting from any process under Section VI.D or Section VI.E. Alternative Resolution Process may also be requested before the initiation of a Complaint. The Title IX Coordinator has discretion to determine whether the parties will be permitted to pursue an Alternative Resolution Process. In general, mediation and other procedures that are similar to mediation will not be used to resolve matters involving an allegation of sexual violence (i.e., Sexual Assault, Dating Violence, Domestic Violence, or any other form of Prohibited Conduct that involves the use of violence). An Alternative Resolution Process is not permitted if such a process would conflict with federal, state, or local law; the university may also decline to permit an Alternative Resolution Process when it determines that the alleged conduct presents a future risk of harm to others.

After receiving a request to pursue an Alternative Resolution Process, the IEX Office will contact both parties to assess mutual interest in the Alternative Resolution Process. If both parties wish to pursue Alternative Resolution, and the Title IX Coordinator agrees that Alternative Resolution is appropriate under the specific facts and circumstances of the case, the IEX Office will initiate the Alternative Resolution Process (https://www.cmu.edu/title-ix/how-to-report-+-options-for-resolution/alternative-resolution-options.html). While every Alternative Resolution Process will be tailored to the facts and circumstances of the individual case, in no case will the facilitator of the Alternative Resolution Process be the same as the investigator or decisionmaker for grievance procedures involving the same matter.

As participation is voluntary, the university does not require parties to waive the right to an investigation and adjudication as a condition of (continuing) enrollment or (continuing) employment, or the exercise of any other right. During any Alternative Resolution Process, either party has the right to withdraw from the process at any time prior to the conclusion of the process. If a Complaint is pending at the time of the withdrawal from the Alternative Resolution Process, the matter will proceed to investigation under Section VI.C or to adjudication under Section VI.D, as appropriate.

Before initiating an Alternative Resolution Process, the university will notify the parties of:

- the allegations;
- the requirements of the Alternative Resolution Process;
- that each party has the right to withdraw their agreement to participate in the Alternative Resolution Process prior to agreeing to a resolution, and can at that time initiate or resume the grievance procedures, as applicable;
- that agreement to a resolution at the conclusion of the Alternative Resolution Process precludes the parties from initiating or resuming grievance procedures arising from the same allegations;
- the potential terms that may be requested or offered in an Alternative Resolution Process agreement, including notice that an alternative resolution agreement is binding only on the parties; and

- which records will be maintained as part of the Alternative Resolution Process and circumstances under which such records could be shared in the event that the Alternative Resolution Process is not completed and grievance procedures are initiated or resumed.
    - Specifically, if the grievance procedures are resumed after an attempted Alternative Resolution Process:
        - neither the university nor a party will access consider, disclose, or otherwise use information, including records, obtained solely through an Alternative Resolution Process as part of the investigation or outcome determination, and
        - in such cases, the Alternative Resolution Process facilitator could serve as a witness for purposes other than providing information obtained solely through the Alternative Resolution Process.

I. Student Emergency Removal; Employee Administrative Leave

Where there is an immediate threat to the physical health or safety of any Students or other individuals arising from alleged Prohibited Conduct, the university may remove an individual from the University's Program or Activity and issue any necessary related no-trespass and no-contact orders during the pendency of the investigation. The university will make the decision to remove an individual from the University's Program or Activity based on an individualized safety and risk analysis.

For Students, an emergency removal decision will be made in accordance with the Safety Intervention Protocol (https://www.cmu.edu/student-affairs/theword/community-policies/safety-intervention-protocol.html) set forth in *The Word*, subject to the limitation of this section. In the event the university removes any person on this basis, the university will provide the affected individual with notice of the decision and an opportunity to appeal, as specified in the Safety Intervention Protocol.

With respect to Employee Respondents, subject to the procedures in the Staff Handbook (for staff employees) or the Faculty Handbook and Appointment and Tenure Policy (for faculty employees), an Employee Respondent may be placed on administrative leave from employment during the pendency of grievance procedures under this Policy. Administrative leave may include complete removal from the workplace or limitations on access to the workplace, and may be imposed with or without pay. In the event administrative leave is imposed, the Respondent is given the opportunity to seek modification or reversal of the leave.

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[1]Discrimination or discriminatory harassment based on family status, parental status, or marital status is Sex-Discrimination where the specific facts and circumstances indicate that the alleged misconduct is sex-based." For example, treating a female parent differently than a male parent or treating an individual in a same-sex marriage differently than an individual in a heterosexual marriage.

VII. Definitions

A. Prohibited Conduct Definitions

Prohibited Conduct means one or more categories of prohibited behavior including:

- Discrimination (including Disparate Treatment);
- Discriminatory Harassment;
- Sex Discrimination
- Sex-Based Harassment, including
    - Quid Pro Quo Sex-Based Harassment,
    - Hostile Environment Sex-Based Harassment,
    - Sexual Assault,
    - Dating Violence,
    - Domestic Violence,
    - Stalking (based on sex), and
- Stalking
- Retaliation; and
- Violation of Protective Measures.

Definitions for each of the types of Prohibited Conduct are provided below.

Discrimination means subjecting an individual or class of individuals to adverse action, including treating an individual or class of individuals differently ("Disparate Treatment") on the basis of a Protected Class.

When Discrimination is based on sex, including sex stereotypes, sex characteristics, sexual orientation, and/or gender identity; Parental, Family, or Marital Status; and/or Pregnancy or Related Conditions, it is considered Sex Discrimination. Sex-Based Harassment, including Sexual Assault, Dating Violence, Domestic Violence, and Stalking (based on sex), is a form of Sex Discrimination, but separately defined under this Policy.

This definition incorporates all exceptions under applicable Title IX regulations, including specifically 34 C.F.R. § 106.31.

Discriminatory Harassment means unwelcome conduct of a verbal, nonverbal, or physical nature, including electronic communication, on the basis of a Protected Class, when such conduct

- Based on the totality of the circumstances, evaluated subjectively and objectively, is sufficiently severe or pervasive that it limits or denies a person's ability to participate in or benefit from any University Program or Activity through the creation of a Hostile Environment.

Discriminatory Harassment and Sex-Based Harassment are different offenses under this Policy. Discriminatory Harassment does not include conduct that meets the definition of Sex-Based Harassment under this Policy.

Sex-Based Harassment means any harassment based on sex, including sex stereotypes, sex characteristics, sexual orientation, gender identity, and/or Pregnancy or Related Conditions, that falls into one or more of the following categories:

1. An Employee, agent, or other person authorized by the university to provide an aid, benefit, or service under any University Program or Activity explicitly or impliedly conditions the provision of such an aid, benefit, or service on a person's participation in unwelcome sexual conduct ("Quid Pro Quo Sex-Based Harassment");
2. Unwelcome sex-based conduct that, based on the totality of the circumstances, evaluated subjectively and objectively, is sufficiently severe or pervasive that it limits or denies a person's ability to participate in or benefit from any University Program or Activity ("Hostile Environment Sex-Based Harassment"). Whether a Hostile Environment is created is a fact-specific inquiry that includes consideration of the following:
    - The degree to which the conduct affected the Complainant's ability to access any University Program or Activity;
    - The type, frequency, and duration of the conduct;
    - The parties' ages, roles within the University's Programs or Activities, previous interactions, and other factors about each party that may be relevant to evaluating the effects of the conduct;
    - The location of the conduct and the context in which the conduct occurred; and/or
    - Other Sex-Based Harassment in the University's Programs or Activities.

    Examples of conduct that may constitute Hostile Environment Sex-Based Harassment include, but are not limited to:
    - Unwanted intentional touching that otherwise does not typically constitute Sexual Assault, defined in this Policy;
    - Unwanted sexual advances, including repeated unwanted requests for dates, or repeated unwanted requests for sexual contact;
    - Unwanted written, verbal, or electronic statements of a sexual nature, including sexually suggestive comments, jokes, videos or innuendos;
    - Exposing one's genitalia, breasts, or buttocks, to another; and/or
    - Touching oneself sexually for others to view.
3. Sexual Assault, Dating Violence, Domestic Violence, Sexual Exploitation and Stalking (based on sex). Each of these forms of Sex-Based Harassment are separately defined below.

Sexual Exploitation means intentionally or knowingly taking sexual advantage of another person or violating the sexual privacy of another when Consent is not present. Sexual Exploitation is a form of Sex-Based Harassment and includes, but is not limited to, the following actions (including when they are done via electronic means, methods, or devices):

- Engaging in sexual voyeurism, including observing or permitting others to witness or observe the sexual or intimate activity (e.g., disrobing, bathing, toileting) of another person without that person's Consent;
- engaging in indecent exposure, or exposing intimate parts (including genitalia, groin, breasts, and/or buttocks), or causing another to expose intimate parts, when Consent is not present;

- recording or distributing information, images, or recordings of any person engaged in sexual or intimate activity in a private space without that person's Consent;
- prostituting another individual;
- causing Incapacitation of another person (through alcohol, drugs, or other means) for the purpose of compromising that person's ability to give Consent to non-consensual sexual activity; or
- actively aiding or assisting another person in committing an act of Sex-Based Harassment, including Sexual Assault, Dating Violence, Domestic Violence, and/or Stalking.

Sexual Assault means a forcible or nonforcible sex offense under the uniform crime reporting system of the Federal Bureau of Investigation, which includes the following acts:

1. Rape means the carnal knowledge of a person, without the Consent of the victim, including instances where the person is incapable of giving consent because of their age or temporary or permanent mental or physical incapacity;
2. Sodomy means oral or anal sexual intercourse with another person, without the Consent of the victim, including instances where the person is incapable of giving consent because of their age or temporary or permanent mental or physical incapacity;
3. Sexual Assault with an Object means to use an object or instrument to unlawfully penetrate, however slightly, the genital or anal opening of the body of another person, without the Consent of the victim, including where the person is incapable of giving consent because of their age or temporary or permanent mental or physical incapacity;
4. Fondling means the touching of the private body parts of another person for the purpose of sexual gratification, without the Consent of the victim, including where the person is incapable of giving consent because of their age or temporary or permanent mental or physical incapacity;
5. Incest means sexual intercourse between persons who are related to each other within the degrees wherein marriage is prohibited by law; or
6. Statutory Rape means nonforcible sexual intercourse with a person who is under the statutory age of Consent in the applicable jurisdiction.

   In the Commonwealth of Pennsylvania, the age of Consent for sexual activity is 16. Minors aged 16 years of age or older can legally consent to sexual activity with anyone they choose, as long as the other person does not have authority over them as defined in Pennsylvania's institutional sexual assault statute. Minors under the age of 13 cannot consent to sexual activity. Minors aged 13-15 years old cannot consent to sexual activity with anyone who is 4 or more years older than they are at the time of the activity.

Dating Violence means violence committed by a person who is or has been in a social relationship of a romantic or intimate nature with the victim and where the existence of such a relationship is determined based on a consideration of the length, type, and frequency of interactions between the persons involved in the relationship.

Domestic Violence means a felony or misdemeanor crime committed by a current or former spouse or intimate partner of the victim under the family or domestic violence laws of the state, or by a person similarly situated to a spouse of the victim; by a person with whom the victim shares a child in common; by a person who is cohabitating with or has cohabitated with the victim as a spouse or intimate partner; or by any other person against an adult or youth victim who is protected from that person's acts under the family or domestic violence laws of the jurisdiction.

Stalking means engaging in a course of conduct directed at a specific person that would cause a Reasonable Person to fear for their safety or the safety of others or suffer substantial emotional distress. Stalking based on sex is a form of Sex-Based Harassment.

Retaliation means intimidation, threats, coercion, discrimination or other adverse action against any person by the university, a Student, or an Employee, or another person authorized by the university to provide aid, benefit, or service under the University's Programs or Activities, for the purpose of interfering with any right or privilege secured by applicable federal, state, or local discrimination laws (e.g., Title IX of the Civil Rights Act of 1972, Title VI of the Civil Rights Act of 1964, Title VII of the Civil Rights Act of 1964, the Americans with Disabilities Act, the Pennsylvania Human Relations Act, etc.), or because the person has reported information to the university, to an external agency, or to law enforcement; made a Complaint; testified, assisted, participated, or refused to participate, in any manner in an investigation, proceeding, hearing, or alternative resolution under this Policy.

Retaliation includes retaliation by peers ("Peer Retaliation"), such as retaliation by a student against another student but also Retaliation by a student against an employee, or by an employee against a student, as well as by an employee against another employee of more or less senior role. An individual need not be a Complainant or Respondent to have committed or been affected by Retaliation. It is not Retaliation for the university to require an employee, or other person authorized by the university to provide aid, benefits, or services as part of University's Programs or Activities to participate as a witness in, or otherwise assist with, any investigation or adjudication under this Policy.

A finding of Retaliation under this Policy is not dependent on a finding that any alleged underlying Prohibited Conduct occurred. Retaliation is also prohibited by the university's Policy Against Retaliation (https://www.cmu.edu/policies/administrative-and-governance/whistleblower.html).

Similarly, charging an individual with a code of conduct violation for making an allegedly materially false statement in bad faith in a Report, Complaint, or in the course of a grievance proceeding under this Policy does not constitute prohibited Retaliation, provided, however, that a determination regarding responsibility, alone, is not sufficient to conclude that any party made a materially false statement in bad faith. Retaliation also does not include pursuit of civil, criminal, or other legal action, internal or external to the university.

Violation of Protective Measures
Any violation of an agreement or order that limits an individual's contact or interactions with another individual. Such agreement or order may have been issued under the authority of the university; another institution; or a local, state, or federal government or court.

B. Definitions Relating to Consent

Consent means a knowing and voluntary agreement to engage in sexual activity at the time of the activity. In order to be valid, consent must be knowing, voluntary, active, present, and ongoing. Consent should be demonstrated through mutually understandable words or actions.

- Silence, remaining still or inactive (passive), or not actively resisting sexual activity does not constitute consent.
- Consent to engage in one sexual activity does not mean consent to engage in another sexual activity. Consent must be obtained each time, at each step of sexual activity.
- Prior consent does not mean future consent. Consent must be obtained each time, at each step of sexual activity, even for those in an ongoing sexual relationship.
- Consent can be withdrawn at any time. If one individual withdraws consent through clear words or actions, the other person must cease sexual activity immediately.
- Consent cannot be obtained through Force, Incapacitation, or Coercion (as defined herein).

Consent may be invalid where one party has lied to or knowingly deceived the other party as to the use of internal or external condoms or other single-use devices used to prevent the spread of sexually transmitted infections during a sexual encounter.

Force means using physical control (such as restraining a person), physical violence (such as hitting, choking, or displaying a weapon), or threats of either, to cause a person to submit to unwanted sexual activity.>

Coercion means using an unreasonable amount of pressure or threats that would overcome the will of a Reasonable Person and cause them to submit to unwanted sexual activity.

Coercion requires more than an attempt to persuade someone to engage in sexual activity. Coercion can include threats, such as threats to cause academic, employment, reputational, or economic harm. When one person expresses that they do not consent to sexual activity or are withdrawing consent for sexual activity, applying continued pressure in order to get the person to submit to unwanted sexual activity can be considered Coercion.

Incapacitation means that a person lacks the ability to make informed, deliberate choices about whether or not to engage in sexual activity. A person is Incapacitated – unable to give consent – because they are:

- under the age of consent (generally 16 years of age in Pennsylvania; *see* definition of Statutory Rape for additional information);
- physically or mentally helpless;
- asleep or unconscious; or
- unaware that sexual activity was requested, suggested, initiated and/or is taking place.

A person may be Incapacitated by the use of alcohol or other drugs. Incapacitation is a state beyond intoxication or drunkenness. A person is not necessarily Incapacitated solely as a result of drinking or using drugs; the level of impairment must be significant enough to render the person unable to give Consent.

For example, a person who is Incapacitated may not be able to answer some or all of the following questions:

- Do you know where you are?
- Do you know how you got here?
- Do you know what is happening?
- Do you know whom you are with?

A person who is Incapacitated may also demonstrate physical signs including but not limited to:

- slurred or incomprehensible speech;
- unsteady manner of walking or inability to walk; and/or
- vomiting or incontinence (a lack of voluntary control over urination and/or defecation).

If a person under the influence of alcohol or drugs decides to participate in sexual activity that they would not participate in while sober, it does not necessarily mean that the person was Incapacitated or that the Consent was not valid.

Importantly, being impaired by alcohol or other drugs is not a defense to a failure to obtain Consent.

C. Protected Class Definitions

Protected Class
Consistent with the university's Statement of Assurance, "Protected Class" means any legally-protected characteristic, including race, color, national origin, sex (including sex stereotypes, sex characteristics, sexual orientation, gender identity, and pregnancy or related conditions), disability, age, parental status, family status, marital status, religion, creed, ancestry, belief, veteran status, genetic information or any other class protected from discrimination under federal, state, or local laws or executive orders.

The following definitions of specific categories of Protected Classes are provided as a helpful resource. To the extent these definitions are inconsistent with any applicable federal, state, or local law the university will apply the applicable legal definition.

Expressing a political view or a view on world events will not be cause alone for determination that behavior is Prohibited Conduct under this Policy.

Race means the ancestry or physical or cultural characteristics associated with a certain race, such as skin color, hair texture or styles, or certain facial features.

Color means a person's pigmentation, complexion, or skin shade or tone.

National Origin means a group of people sharing a common language, culture, ancestry, race, and/or other social characteristics.

Sex means sex stereotypes, sex characteristics, sexual orientation, gender identity, and/or pregnancy or related conditions.

Sexual Orientation means a person's actual or perceived predisposition or inclination toward a particular type of sexual activity or behavior.

Gender Identity means an individual's sense of their gender, which may or may not be different from their sex assigned at birth.

Sex Stereotypes means fixed or generalized expectations regarding a person's aptitudes, behavior, self-presentation, or other attributes based on sex.

Sex Characteristics means physiological sex-based characteristics including, but not limited to, a person's anatomy, hormones, and chromosomes associated with male or female bodies and intersex traits.

Pregnancy or Related Condition means (1) Pregnancy, childbirth, termination of pregnancy, or lactation; (2) Medical conditions related to pregnancy, childbirth, termination of pregnancy, or lactation; (3) Recovery from pregnancy, childbirth, termination of pregnancy, lactation, or related medical conditions.

Note, in some jurisdictions, including the City of Pittsburgh, the "partner" of a person who is pregnant or has a pregnancy related condition is protected from discrimination and may be entitled to certain reasonable accommodations. For more information, please see Human Resource's Pregnancy Support and Accommodations Policy [pdf] (https://www.cmu.edu/hr/assets/hr/pregnancy-support-policy.pdf).

Parental Status means the status of a person who, with respect to another person who is under the age of 18 or who is 18 or older but is incapable of self-care because of a physical or mental disability, is (1) a biological parent, (2) an adoptive parent, (3) a foster parent, (4) a stepparent, (5) a legal custodian or guardian, (6) in loco parentis with respect to such person, or (7) actively seeking legal custody, guardianship, visitation, or adoption of such person.

Marital Status means the state of being married or not married.

Family Status refers to the configuration of a person's family or their role in a family.

Disability means a physical or mental impairment that substantially limits one or more major life activities, a person who has a history or record of such an impairment, or a person who is perceived by others as having such an impairment.

Age
How old a person is.

Religion means all aspects of religious observance, religious practice, religious creed, and religious belief or nonbelief, as defined under Title VII of the Civil Rights Act of 1964 and similar federal, state and local religious discrimination laws.

Ancestry means the common physical, cultural or linguistic characteristics of a person's ancestors.

Veteran means a person who served in any branch of the U.S. military.

Genetic Information means with respect to any person, information about (i) such person's genetic tests, (ii) the genetic tests of family members of such person, and (iii) the manifestation of a disease or disorder in family members of such person.

D. Policy Definitions

Advisor means, an individual who provides support and advice for the Complainant or Respondent. The Complainant and Respondent may have an Advisor of their choice, who may be, but is not required to be, an attorney.

Complainant means a Student, Employee, or other person who is alleged to have been subject to conduct that could constitute Prohibited Conduct under this Policy. In some cases, a Complainant may be different from the person who initially reports information to the university. In the event a Complaint is brought by the IEX Office, the individual affected by the alleged Prohibited Conduct that is the subject of the Complaint remains the Complainant, and the Civil Rights Coordinator does not become the Complainant.

Disciplinary Sanctions
Consequences imposed on a Respondent following a determination that the Respondent is responsible for having committed Prohibited Conduct.

Employee means person who is employed by the university to perform one or more of the following roles: regular instructional faculty, supplemental instructional faculty, research track faculty, visiting faculty, librarians, archivists, curators, graduate student instructors, graduate student staff assistants, graduate student research assistants, postdoctoral research fellows, and all regular and temporary Staff.

Faculty/Faculty Member means all individuals who hold appointments on the tenure-track, research-track, teaching-track, librarian/archivist-track, and special faculty track of the university, as well as individuals holding emeritus faculty status.

Complaint means an oral or written request to the university that objectively can be understood as a request for the university to investigate and make a determination about alleged Prohibited Conduct, as set forth in the procedures outlined in Section VI (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/complaint-resolved.html). It is the policy of the university to confirm a Complainant's request in writing prior to initiating the grievance procedures. A Complaint can be made by a Complainant[1] or the IEX Office as set forth in Section VI.A (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/complaint-resolved.html#a). A Complainant must have been enrolled, employed, or otherwise participating or attempting to participate in the university's Programs or Activities at the time the alleged Prohibited Conduct occurred in order to file a Complaint under this Policy, although the Complainant need not be enrolled, employed, or otherwise participating or attempting to participate in the university's Education Program or Activity at the time the Complaint is made. constitute Prohibited Conduct, the Title IX Coordinator has discretion to file a Complainant, as detailed in Section VI.A (https://www.cmu.edu/policies/administrative-and-governance/sexual-misconduct/complaint-resolved.html#a), even if the report was not submitted by an individual who is participating or attempting to participate in the university's Education Program or Activity. With respect to allegations of Sex Discrimination other than Sex-Based Harassment, a Complaint may be brought by any Student or employee, or any other person who was participating or attempting to participate in the Education Program or Activity at the time the alleged conduct took place.

Preponderance of the Evidence means to prove that something is more likely than not.

Reasonable Person means a person using average care, intelligence, and judgment in the known circumstances.

Relevant
Related to the allegations of Prohibited Conduct at issue and whether or not the alleged Prohibited Conduct occurred. Questions are Relevant if they may aid in showing whether the alleged Prohibited Conduct occurred, and evidence is Relevant if it may aid a decisionmaker in determining whether the alleged Prohibited Conduct occurred. The following evidence is impermissible (and will not be considered Relevant) even if it would otherwise be considered Relevant:

- evidence protected under a privilege recognized by federal or state law, unless the person holding the privilege has waived it voluntarily;
- records that are made or maintained by a physician, psychologist, or other recognized professional or paraprofessional in connection with the provision of treatment to a Party or witness, unless the person has voluntarily consented, in writing, to the use of such records in the Grievance Procedures; and/or
- evidence and questions about the Complainant’s sexual interests or prior sexual conduct, unless:
  - offered to prove that someone other than the Respondent committed the conduct alleged, or
  - if concerning specific incidents of prior sexual activity with the Respondent which are offered to prove consent.

Such impermissible evidence will not be accessed, considered, disclosed, or used, except to determine whether one of the preceding exceptions applies.

Remedies
Measures provided, as appropriate, to a Complainant or other person whose equal access to the university’s Programs and Activities was determined to have been limited or denied by Prohibited Conduct, in order to restore or preserve that person’s access.

Report
Any notice of conduct that may constitute Prohibited Conduct. A Report may come from any individual, not just a Complainant. Not every Report is or will result in a Complaint.

Respondent means an individual who is reported to have engaged in Prohibited Conduct. In the event that a Complaint alleges that a university policy or practice discriminates on the basis of Protected Class, the university is not considered a Respondent. In such cases, the university will follow this Policy, including the Grievance Procedures, although the university will, necessarily, not be entitled to certain procedural rights and steps afforded to individual Respondents. In the event a Complaint against an individual Respondent is based on actions the Respondent took in accordance with a university policy or practice, the Complaint may, in the university’s sole discretion, be amended to substitute the university as Respondent. This determination will be made after a consideration of factors including, but not limited to, whether the individual was, in fact, following the university policy or practice; what actions the individual took; and whether the individual could be subject to Disciplinary Sanctions.

Staff/Staff Member means all Employees of the university who do not hold faculty appointments. Staff does not include individuals whose primary relationship with the university is as a Student.

Student means a person who gained admission to the university.

University's Programs or Activities
Conduct that takes place in the “University’s Programs or Activities” means conduct that is subject to the university’s disciplinary authority and which occurs in the United States, including on-campus, or, if applicable, in any building owned or controlled by a student organization recognized by the university. Conduct is subject to the university’s disciplinary authority if it occurs in a location, at an event, or in a circumstance where the university exercises substantial control over both the Respondent and the context in which the conduct occurs. However, the university will address conduct contributing to a Hostile Environment even if the underlying conduct itself occurred outside the University’s Programs or Activities, including if it occurred outside the United States, and including conduct occurring online via computer and internet networks or on digital platforms, including social media sites). University Programs or Activities also includes the conduct within the university’s disciplinary authority at the university’s international locations, such as Carnegie Mellon University Qatar and Carnegie Mellon University Africa.

[1]A Complaint may also be brought by a parent, guardian, or other authorized legal representative with the legal right to act on behalf of a Complainant, where applicable.

VIII. Additional Provisions Pertaining to Parental, Family, or Marital Status, and Pregnancy or Related Conditions

In determining whether a person satisfies any university admissions policy or criterion, or in making any offer of admission, the university will treat Pregnancy or Related Conditions in the same manner and under the same policies as any other temporary medical condition.

The university will not make pre-admission or pre-employment inquiry as to the Marital Status of an Applicant, including whether an Applicant is "Miss or Mrs." The university may ask an Applicant to self-identify their sex, but only when asking this question of all Applicants. The response will not be used as a basis for discrimination.

The university will not adopt or apply any policy, practice, or procedure, or take any employment action, concerning the current, potential, or past Parental, Family, or Marital Status of a Student, Employee, or applicant that treats persons differently on the basis of sex, or which is based upon whether an Employee or applicant for employment is the head of household or principal wage earner in such Employee’s or applicant’s family unit.

The university will not discriminate against, establish or follow any policy, practice, or procedure that discriminates against, or exclude from employment any person on the basis of current, potential, or past Pregnancy or Related Conditions.

IX. Title IX Coordinator

Carnegie Mellon has appointed a Title IX Coordinator to oversee the university’s compliance with Title IX of the Education Amendments of 1972, Title VI of the Civil Rights Act of 1964, and other applicable federal, state, and local civil rights laws. The Title IX Coordinator is responsible for this Policy, as well as the Statement of Assurance.

The university’s Title IX Coordinator is:

Elizabeth Rosemeyer
Assistant Vice Provost for Diversity, Equity and Inclusion & Title IX Coordinator
4615 Forbes Avenue, Suite 330
Pittsburgh, PA 15213
(412) 268-7125
institutionalequity@andrew.cmu.edu

In accordance with applicable Title IX regulations, the Title IX Coordinator is responsible for the following:

- Taking prompt and effective steps to ensure that Sex Discrimination does not continue or recur, and to remedy its effects;
- Monitoring CMU’s Programs or Activities for barriers to reporting conduct that may constitute Sex Discrimination and taking steps reasonably calculated to address such barriers;
- Facilitating the provision of a non-discriminatory environment and equal access to individuals experiencing Pregnancy or Related Conditions; and
- When notified of conduct that reasonably may constitute Sex Discrimination,
  - Treating Complainants and Respondents equitably;
  - Offering and coordinating Supportive Measures for the Complainant and, if Alternative Resolution Process or Grievance Procedures are pending, the Respondent;

- Notifying Complainants or, if different, individuals making Reports, of the Alternative Resolution Process and Grievance Procedures, as available and appropriate;
- Notifying the Respondent of the Alternative Resolution Process and Grievance Procedures, as available and appropriate, if a Complaint is made;
- In the event of a Complaint, initiating the Grievance Procedures or, if available and appropriate and requested by all Parties, the Alternative Resolution Process; and
- In the absence of a Complaint made by a Complainant, or in the event of the withdrawal of any or all of the allegations in a Complaint, determining whether to initiate a Complaint.

The Title IX Coordinator manages the Office for Institutional Equity and Title IX ("IEX Office"). Employees in the IEX Office are designees of the Title IX Coordinator and may carry out the duties and responsibilities of the Title IX Coordinator. The Title IX Coordinator may also delegate certain responsibilities to other university employees.

X. Recordkeeping

There is a seven-year record retention period for:

- Reports; Complaints; and records documenting the response to Reports and Complaints, including any Supportive Measures provided, any emergency removals or administrative leave imposed, and any Alternative Resolution Process or grievance procedures undertaken, including the resulting outcome (e.g., the result of any Alternative Resolution Process, determinations of responsibility, Disciplinary Sanctions imposed on the Respondent, Remedies provided to the Complainant, appeals and the results of such appeals);
- Any records documenting action taken by university to address Reports of Sex Discrimination, prevent its recurrence, and remedy its effects; to address any barriers identified to reporting such conduct; and to educate employees about their mandatory reporting responsibilities;
- All materials used to provide required training;
- Any audio or audiovisual recording or transcript required to be retained; and
- Any other records documenting the actions taken to satisfy the university’s obligations to prevent discrimination and ensure equal access for individuals due to Pregnancy or Related Conditions, including facilitating reasonable modifications for Students and facilitating temporary adjustments, leave, and/or lactation time and space for Employees.

Policies on Examinations

www.cmu.edu/policies/student-and-student-life/examination-policies.html (https://www.cmu.edu/policies/student-and-student-life/examination-policies.html)

Preamble

The Faculty Senate adopted the following policies on the administration of examinations for the undergraduate courses (defined as courses that are numbered 6xx or below). These policies represent an understanding between faculty and student concerning an important but often stressful period, especially at the conclusion of each academic semester and at mid-semester. There should be no expectation that the following points will cover every conceivable situation. The student should anticipate the demands of the exam schedule, plan accordingly and early, and be prepared. The faculty should recognize that the student is encumbered with many tightly orchestrated and intensive obligations during this period over which they have no control: expectations should be reasonably consistent with the number of course units and, of course, should be made known to the student well in advance of the final examination period, preferably as part of the course syllabus.

In order to help students plan their time and study optimally for examinations, this document lays out in some detail the policies regarding final and in-term examinations. Instructors are requested to provide notification of the major in-term examinations in the course syllabus. The final examination date is posted early in the semester. It is the responsibility of the student to give his or her instructor sufficient notice and to work with the instructor to reschedule examinations if this is needed.

Definitions

- Final examination period.The university's official final examination period begins on the Monday immediately following the last day of classes and continues through the last day of scheduled final examinations, with the exception of reading day(s).
- Scheduled final examinations. Scheduled final examinations are those scheduled by Enrollment Services.
- Self-scheduled examinations.An instructor may choose not to fix a schedule for the final examination, but instead allow each student to choose the examination time; such exams are called self-scheduled examinations.
- Final examinations. Final examinations can either be comprehensive, covering all course materials, or non-comprehensive, covering only a part of the course.
- In-term examinations. Major examinations during the semester are referred to here as in-term examinations.

I. In-Term Examinations

1. All in-term examinations should be given during the regularly scheduled class time. However, if the exam requires additional time to complete, then examinations may be administered outside of regularly scheduled class time.
2. No examinations given outside of class time (excluding make ups and self-scheduled examinations) shall be administered on a Friday after 4:30 pm, or at any time Saturday or Sunday.
3. The instructor administering an exam (or another required class event) that falls outside class time must make any and all reasonable accommodations to provide an alternative time to students who have conflicts with the proposed time period, including those conflicts due to activities, meetings, other classes, etc. (provided that the instructor is notified of such conflict in a timely manner).
4. No student shall be required to take more than two full-period in-class or out-of-class examinations on the same day. It is the responsibility of the student to notify the instructor in a timely manner of their circumstance so that appropriate accommodations can be made.

II. Final Examinations

1. All scheduled final examinations are held at the end of the semester during the university's official final examination period. Comprehensive final examinations are not required for each course, but are given at the option of the department or instructor. The reading day and weekend preceding the examination days shall never be used for examination purposes of any kind, unless a student opts to take a self-scheduled examination during this time. Non-comprehensive final examinations or final projects (but not both) are allowed during this final examination period only in courses that do not give a final comprehensive examination.
2. Instructors are expected to return all work assigned no later than the last regular day of classes in courses for which there is a final examination. In cases when this is not possible, an answer key, solution sets or equivalent feedback should be provided unless the final examination will not cover material in work that has not been returned.
3. No other coursework, including laboratory or studio work, will be due during the final examination period unless it is assigned in advance and in lieu of the course's final examination. Regardless of whether there is a final examination in the course, no classes other than review sessions shall be held during the final examination period. Review sessions should be scheduled for optimal attendance, and a serious effort should be made to accommodate students who cannot attend. In appreciation of the time required to prepare for final examinations, no other examinations, portfolio reviews, critiques or juries shall be scheduled for the last class day of a course with a final examination.
4. Instructors shall never exert or submit to pressures to move an examination so that people can leave earlier nor pressure students to take an examination on a reading day or weekend preceding examinations.
5. No student is required to take more than two scheduled examinations that start within a 25-hour period. A student who has more than two examinations scheduled within a 25-hour period or has two examinations scheduled at the same time should first contact the instructors of the courses for assistance in resolving conflicts. If the problem cannot be resolved by that means, the student should contact the associate dean of his or her home college.
6. Take-home final examinations shall be given for any 24-hour period of the student's choosing during the final examination period.
7. Students are expected to present themselves at the place assigned at the start of the examination; late arrival will reduce the total time a student has to complete the examination, unless instructor's course policy indicates otherwise. Instructors reserve the right to require

attendance within a specific time period. Students who miss an examination with a reasonable excuse and wish to petition for a make-up final examination should check with the instructor. Instructors are encouraged to include late arrival policy and make-up exam policy in the course syllabus.

8. Any student shall be permitted to review his or her corrected, graded final examination in the presence of an instructor or a teaching assistant. Any controversy arising from this review shall be dealt with in accordance with the university procedure for the appeal of grades and academic actions. A final examination that is not returned to a student will be kept available for a year for review. In the event that the instructor or teaching assistant is not available for the review, the responsibility shall rest with the department head of the instructor offering the course or his or her designee. Since instructors are expected to return all work assigned before the final examinations, they are not responsible for retaining unclaimed coursework.
9. Concerns related to final examination, complaints about violations of the final examination policy or alterations of the final examination schedule should be directed to the department head of the instructor offering the course or to the associate dean of the student's home college.

Contact

Questions concerning this policy or its content should be directed to the Vice Provost for Education, (412) 268-5865.

Final Examination Conflict Guidelines

Recognizing that students will, on occasion, encounter foreseeable or unforeseeable conflicts with scheduled final examinations, the following guidelines have been approved by the University Education Council (UEC), the Associate Deans' Council (ADC), and the Associate Deans for Graduate Programs (ADGP) to inform the actions of students and the decisions of instructors.

Foreseeable Conflicts:

Before negotiating any exam conflicts, students should recognize the following expectations. Students should carefully consider the dates of each semester's final exam period as reflected in the university's official academic calendar. Until the university publishes the detailed final examination schedule (usually by early October in the Fall semester and by late February in the Spring semester), students should plan according to the assumption that their final exams could be scheduled for any day/time during the final exam period. Therefore, students should avoid making any personal arrangements (such as travel) that could ultimately conflict with the final exam period.

In developing the final examination schedule, the University Registrar's Office deploys significant effort in consultation with associate deans to minimize direct and 25-hour conflicts for individual students. Once the final exam schedule is published for the semester, each student should immediately review the schedule to determine whether there are conflicts. If the student's schedule presents any final exams that directly conflict with each other, or if the student's schedule presents more than two final exams to begin in a twenty-five hour period, then the student is responsible for immediately initiating the following process so that the relevant instructors can reach a timely and effective resolution that is consistent with university policy (noting that no action is necessary if a student voluntarily elects to take the exams according to the published schedule):

1. The student should begin by discussing the conflict with all relevant instructors to determine if they can suggest a resolution. This discussion should be completed at least two weeks prior to the exams.
2. If one of the course instructors offers an alternate time for the exam, the student must agree to that resolution unless another exam conflicts with the alternate proposed time.
3. If a resolution cannot be found, the following hierarchy is recommended for compromise (Student’s Home Department> Student’s College> Smallest Course Size> Higher Course level):
    - If one of the courses is offered in the student’s home department, the home department should be the first to accommodate.
    - If the course is offered within the student’s home college, then the student’s college should accommodate a course that is not within the student’s college.
    - An instructor teaching a smaller course size should accommodate before an instructor from a larger course size accommodates.
    - Finally, if a resolution still has not been reached, an instructor teaching a higher course level should accommodate before an instructor from a lower course level accommodates.

At any point during this process, the student's academic advisor or academic associate dean from the home academic college may be consulted to verify the existence of the conflict and assist in the negotiation and resolution.

Other foreseeable conflicts may be personal in nature, such as a religious holy day or observance, or a singular, significant obligation. As stated earlier, students are expected to review the final exam schedule as soon as it is published to identify such conflicts. A student faced with such a conflict should first exhaust all reasonable means to otherwise resolve it. If such efforts are unsuccessful, then the student should immediately contact the instructor and explain the circumstances, recognizing that the current Policy on Examinations (https://www.cmu.edu/policies/student-and-student-life/examination-policies.html) does not require the instructor to offer an alternate exam time in response to foreseeable, personal conflicts. The mutual respect and goodwill between instructor and student should guide their negotiation of such conflicts as they attempt to balance the student's needs with those of the academic enterprise. At any point in the process, the student's academic advisor, academic associate dean and/or student affairs liaison may be consulted to assist in identifying reasonable accommodations or solutions.

Students hoping to resolve cases involving foreseeable conflicts should expect that their instructors may require them to take a rescheduled final examination on the Make Up Final Exam Day (https://www.cmu.edu/hub/registrar/exams-and-grading/make-up.html).

Unforeseeable Conflicts

In exceptional circumstances, a student may encounter a medical, personal or family emergency that unexpectedly interferes with their ability to participate in a scheduled final examination. When encountering such a situation, the student should contact the instructor as soon as is reasonably possible, and ideally before the final examination has been administered. The student's academic advisor, academic associate dean and/or student affairs liaison may serve as both advocate for the student and point of verification for the instructor.   After reviewing the matter, should an accommodation be granted by the instructor, the instructor may elect to institute one of several options, including: rescheduling the exam for later in the final examination period; assigning an "I" incomplete grade until a make-up exam can be administered in the following semester; or utilizing another method for resolving missed exams that has been outlined in the course syllabus.

Student Health Insurance Policy

www.cmu.edu/policies/student-and-student-life/student-health-insurance.html (https://www.cmu.edu/policies/student-and-student-life/student-health-insurance.html)

Reason for Policy

The high cost of health care in the United States presents a potentially serious health and financial risk to students and their accompanying dependents. The absence of adequate insurance coverage can result in temporary or permanent interruption of a student's education. The university is committed to offering student health insurance that provides access to quality health care and achieves a balance between premium cost and adequate coverage without overburdening students' financial resources. This balance is best achieved through a mandatory/hard waiver insurance program that mitigates the effect of adverse selection.

Policy Statement General Requirements

All full-time students are required to carry health insurance and will be assessed a charge for the individual basic mandatory plan offered through the university student health insurance program. The charge will appear on the invoice of the first semester of attendance in the academic cycle. The student is required to take one of the following three actions:

1. Enroll in the basic plan as charged.
2. Upgrade the benefit plan by enrolling in the enhanced student health insurance options during the open enrollment period.
3. Apply for a waiver from the mandatory plan.

Requirements for Waiver

Application for a waiver from the university student health insurance plan must be made to Student Health Services by the last day of the open enrollment period. Students applying for waiver must provide documentation of continuing coverage verifying that they are enrolled as the dependent, partner/spouse or principal in an employer or government-sponsored insurance plan. Additionally, the plan must meet minimum standards for coverage as set forth below:

- It must offer at least 75% coverage for inpatient and outpatient medical services in the Pittsburgh area.
- It must include mental health benefits.
- The deductible must not exceed $500 per accident or illness.
- It must offer medical benefits of at least $50,000 per accident or illness.
- It must cover pre-existing conditions.

Contact

Questions should be directed to Student Health Services at 412-268-2157.

Carnegie Mellon Freedom of Expression Policy

www.cmu.edu/policies/administrative-and-governance/freedom-of-expression.html (https://www.cmu.edu/policies/administrative-and-governance/freedom-of-expression.html)

Freedom of Expression Policy

Carnegie Mellon University values the freedoms of speech, thought, expression and assembly - in themselves and as part of our core educational and intellectual mission. If individuals are to cherish freedom, they must experience it. The very concept of freedom assumes that people usually choose wisely from a range of available ideas and that the range and implications of ideas cannot be fully understood unless we hold vital our rights to know, to express, and to choose. The university must be a place where all ideas may be expressed freely and where no alternative is withheld from consideration. The only limits on these freedoms are those dictated by law and those necessary to protect the rights of other members of the university community and to ensure the normal functioning of the University.

Rights

On Carnegie Mellon's Campus, anyone may distribute printed material, offer petitions for signature, make speeches, and hold protests or demonstrations outside university buildings. All such activities must be peaceful, avoiding acts or credible threats of violence and preserving the normal operation of the university. No event shall infringe upon the rights or privileges of anyone not in sympathy with it, and no one will be permitted to harm others, damage or deface property, block access to university buildings or disrupt classes. The enforcement of these conditions will not depend in any way on the message or sponsorship of the act or event. When guests are invited by a recognized campus organization, they may express their ideas not because they have a right to do so, but because members of the campus community have a right to hear, see, and experience diverse intellectual and creative inquiry. Defending that right is a fundamental obligation of the university. Controversy cannot be permitted to abridge the freedoms of speech, thought, expression or assembly. They are not matters of convenience, but of necessity.

Responsibilities

Freedom of expression must be at once fiercely guarded and genuinely embraced. Those who exercise it serve the Carnegie Mellon community by accepting the responsibilities attendant to free expression. University organizations that sponsor invited guests to campus are expected to uphold Carnegie Mellon's educational mission by planning carefully to create safe and thoughtful experiences for those involved. Hosts are responsible for the behavior of their guests and should exercise due care to ensure that all participants abide by relevant university policies.

Considerations for Planning Campus Events

Consistent with the rights and responsibilities outlined in the university's policy on Freedom of Expression, university hosts must follow all applicable policies related to space reservation, use, safety and security, keeping in mind the responsibility to have campus police present for any event with 100 or more persons in attendance.

Hosts should consider the items below as guidance in planning campus events, recognizing that not all of the items will apply to all events:

1. A public declaration of the event, its purpose, the identification of sponsors and co-sponsors, and contact information for those seeking further information.
2. A plan for advertising the event, including advance notice to relevant members of the community who may wish to co-sponsor, protest, or host other events in response to the planned activity.
3. Where appropriate, a clear and detailed contract with outside speakers, artists, or suppliers of services to ensure continuity of purpose and the ability of the host to control the event reasonably, consistent with the host's intent.
4. A plan for access to the event, including notifying the community of reserved seats, ticketing, queuing protocol, or other relevant details or restrictions well in advance of the activity.
5. A provision for security before, during, and after events, managed in coordination wit the University Police. Specifically, non-university security personnel must have their allowable duties clearly delineated, in partnership with the University Police, with their role generally limited to personal security and not to space management.
6. A plan for participant engagement at the event, such as through a question and answer session, if relevant, with a clear delineation of the planned ground rules for the event set out well in advance.
7. A strategy for hosting of additional events, discussions, or town meetings before or after a principal event to help provide a context in which the principal event may be best experienced.

The Office of Student Activities and the Office of the Dean of Student Affairs may assist in, or directly coordinate, some aspects of campus events, such as fostering discussions preceding or following an event, or accommodating an opposing view at an alternative event. It is assumed that the spirit of community, both among people with groups with opposing views, as well as between event sponsors and the Student Activities and Student Affairs staffs, will foster communication and cooperation in the planning of campus events. Wherever possible, Student Affairs will work in concert with University Police to notify occupants of buildings in advance of any potential disruption caused by such events.

Security Personnel Statement

At times, members of the campus community or their invited guests may have a legitimate basis for being accompanied by independent security personnel. It is incumbent upon the host of such an individual to ensure that University Police approve in advance the presence and scope of involvement of any such security personnel.

Student Immunization Policy

www.cmu.edu/policies/student-and-student-life/immunizations.html (https://www.cmu.edu/policies/student-and-student-life/immunizations.html)

Reason for Policy

Vaccine-preventable diseases continue to occur on American campuses and pose a significant threat to the public health of the campus community. Outbreaks not only impose a significant cost to infected individuals in terms of mortality and morbidity but also can be costly to the university by disrupting university activities.

Policy Statement

The goal of the Student Health Services and the university is to provide adequate protection of the campus community against vaccine-preventable diseases by requiring students to be vaccinated against and/or screened for certain highly contagious diseases. This goal can best be achieved through a mandatory prematriculation immunization requirement. The following requirements are consistent with Pennsylvania State Law and with the recommendations of the American College Health Association, the Advisory Committee on Immunization Practices.

Requirements for All Full-Time Students

All entering full-time students born after 1956 must demonstrate proof of immunity against measles, mumps and rubella by either providing dates of inoculation of two doses of the measles vaccine and at least one dose of mumps and rubella or providing blood titers that demonstrate immunity to these infections or providing documentation from a physician of having had the infection.

Additional Requirements for Students Residing in University Housing

- All students residing in university housing must demonstrate immunity against Hepatitis B by either providing documentation of having initiated or completed the three dose vaccination series.
- The student is expected to complete the series within six months of initiation of the series.
- All students residing in university housing must provide documentation of having been vaccinated against meningococcal meningitis within three years prior to enrollment in the university.
- All full-time international students must provide documentation of having had a PPD skin test to screen for tuberculosis within one year prior to enrollment in the university regardless of prior BCG inoculation. If the results of the skin test are positive, a chest x-ray is required.

Request for Waiver

- A student may request a waiver from any vaccination for medical reasons or if vaccination conflicts with personal or religious beliefs. Application for waiver is to be made in writing to Student Health Services prior to the first day of classes in his/her first semester of attendance at the university. In the case of an outbreak of a contagious disease on campus for which the student has not been immunized, the university reserves the right to ask the student to leave campus until the outbreak is over.
- A student may request a waiver from tuberculin skin testing if the student is from a country that has been identified by the Centers for Disease Control as having low prevalence of tuberculosis.

Penalty for Noncompliance

- If the student fails to comply with the immunization policy, the Student Health Services will notify Enrollment Services who will place a hold on the student's registration until the requirements are met and assess a fee of no more than $50 to the student's account.
- Additionally, if the student is a resident in university housing and fails to comply with the immunization requirements, they will be removed from housing.

Contact

Questions should be directed to Student Health Services at 412-268-2157.

Related Policies and Procedures

The university complies with OSHA regulations regarding occupational exposure to blood-borne pathogens. Questions regarding these regulations should be directed to Environmental Health & Safety at 412-268-8182.

Additional recommendations

A PPD skin test for tuberculosis is recommended for domestic students who have traveled to an area where tuberculosis is endemic. All students should have a booster dose of tetanus/diphtheria every ten years after completion of the primary series.

Intellectual Property Policy

www.cmu.edu/policies/administrative-and-governance/intellectual-property.html (https://www.cmu.edu/policies/administrative-and-governance/intellectual-property.html)

1. Purpose

The policy reflects the following goals:

- To create a university environment that encourages the generation of new knowledge by faculty, staff, and students.
- To facilitate wide transfer of useful inventions and writings to society.
- To motivate the development and dissemination of intellectual property by providing appropriate financial rewards to creators and the university, and administrative assistance to creators.
- To ensure that the financial return from the development of intellectual property does not distort decisions and operations of the university in a manner contrary to the mission of the university.

The policy is based upon the following principles relating the university to society:

- The mission of the university remains the generation and dissemination of knowledge.
- Intellectual property will be generated within the university, and there exists an obligation to disseminate it. An interface is needed if better technology transfer is to be achieved, and the university will provide mechanisms for that function.

The policy is based upon the following principles relating faculty, staff and students to the university:

- Intellectual property is created by individuals, or by groups of individuals, who are entitled to choose the course of disclosure; academic freedom of individuals is a higher priority than possible financial rewards.
- There exists a historical tradition allowing authors to retain ownership of intellectual property rights from textbooks and works of art.
- The university is the support of the whole campus community, and is thereby entitled to share in financial rewards.
- There should be incentives for all parties to pursue financial rewards together, consistent with the expressed goals of the policy. The distribution of these rewards should reflect, insofar as possible, the creative contributions of the creator, and the resources contributed by and risks assumed by both the creator and the university in developing intellectual property.
- Since it is frequently difficult to assess risks meaningfully, resources and potential rewards, negotiated agreements are to be encouraged whenever possible.

2. Definitions

Certain terms are used in this document with specific meanings, as defined in this section. These definitions do not necessarily conform to customary usage.

Intellectual Property includes any patentable invention, any copyrightable subject matter, or trade secret. It also includes works of art, and inventions or creations that might normally be developed on a proprietary basis.

University means Carnegie Mellon.

Student means any full-time or part-time graduate or undergraduate student, regardless of whether the student receives financial aid from the university or from outside sources. It is the responsibility of students who are also employees of other outside entities to resolve any conflicts between this policy and provisions of agreements with their employers prior to beginning any undertaking at the university that will involve the development of intellectual property.

Faculty means members of the university's Faculty Organization as defined in the Faculty Handbook, plus instructors and special faculty appointments (even in the first year), and part-time faculty.

Staff means any employee of the university other than students and faculty as defined above. If a student is also a part-time university employee, he is considered as staff with regard to intellectual property developed as a result of his employment, and as a student with regard to other intellectual property. A full-time non-faculty employee who is also taking one or more courses is considered to be staff. Visitors to the university who make substantial use of university resources are considered as staff with respect to any intellectual property arising from such use. (The distinction between faculty and staff does not affect intellectual property rights except for representation on the Intellectual Property Adjudication Committee [see Section 5].)

Creator means any person or persons who create an item of intellectual property.

Net proceeds to the university means all proceeds received by the university on intellectual property that it assigns, sells or licenses, minus any application, litigation, interference, or marketing costs directly attributable to the intellectual property being licensed. Deducted costs shall be reasonable and fair, and shall be properly disclosed; the sources and amounts of compensation shall also be properly disclosed.

Net proceeds to the creator means all proceeds received by the creator from intellectual property owned by him that he sells, assigns or licenses, less the costs of application, legal protection, or litigation, interference, travel and other marketing costs directly attributable to the intellectual property being exploited. Such net proceeds do not include compensation legitimately received by the creator for consulting services or interest or other return on invested labor or capital. Deducted costs shall be reasonable and fair, and shall be properly disclosed; the sources and amounts of compensation shall also be properly disclosed.

Substantial use of university facilities means extensive unreimbursed use of major university laboratory, studio or computational facilities, or human resources. The use of these facilities must be important to the creation of the intellectual property; merely incidental use of a facility does not constitute substantial use, nor does extensive use of a facility commonly available to all faculty or professional staff (such as libraries and offices), nor does extensive use of a specialized facility for routine tasks. Use will be considered “extensive” and facilities will be considered “major” if similar use of similar facilities would cost the creator more than $5000 (five thousand dollars) in constant 1984 dollars if purchased or leased in the public market. Creators wishing to directly reimburse the university for the use of its facilities must make arrangements to do so before the level of facilities usage for a particular intellectual property becomes substantial. (This provision is not intended to override any other department or university policy concerning reimbursement for facilities usage.)

In general:

In any given year the equivalent figure for a particular amount of money in constant 1984 dollars will be obtained by multiplying that amount of money by the ratio of the most recent quarterly Disposable Personal Income Deflator divided by the average monthly Disposable Personal Income Deflator for the year 1984.

As used in this policy, the masculine gender includes the feminine gender, singular or plural, wherever appropriate.

3. Policy Provisions

This section states the policies concerning ownership of intellectual property created at the university. In order of precedence, ownership of intellectual property shall be as follows:

3-1. Externally Sponsored Work

Ownership Provisions: Intellectual property created as a result of work conducted under an agreement between an external sponsor and the university that specifies the ownership of such intellectual property shall be owned as specified in said agreement. If the university declares itself to be a sponsor, but does not declare itself to be the owner of the intellectual property, ownership shall be determined in accordance with 3-6-4 below.

Procedural Provisions: It is the responsibility of the Office of Sponsored Research of the university to inform each person whose intellectual property rights are limited by an externally sponsored contract of the intellectual property provisions of that contract in advance of the beginning of work thereon. Such notice is to be in writing and the university may require written acknowledgment of such provisions by any person working on externally sponsored projects. A summary of external sponsorship agreements limiting the intellectual property rights of potential creators will be maintained by the Office of Sponsored Research and will be available to the general university community.

If the university fails to notify a creator, effectively and in advance, of limitations imposed on his intellectual property rights by external sponsorship agreements, the creator is entitled to receive from the university 50% (fifty percent) of the net proceeds to the university resulting from his intellectual property.

3-2. Internally Sponsored Work

Ownership Provisions: When the university provides funds or facilities for a particular project to the extent of substantial use, it may also choose to designate itself as sponsor of that work. The university may declare itself the owner of intellectual property resulting from said work. In such cases the university must specify in advance the disposition of any intellectual property rights arising from the project. If the university declares itself to be a sponsor, but does not declare itself the owner of the intellectual property, ownership shall be determined in accordance with 3-6-4 below.

Procedural Provisions: It is the responsibility of the Office of Sponsored Research of the university to inform each person whose intellectual property rights are limited by internally sponsored work of the intellectual property ownership rights specified by the university as to that work in advance of the beginning of work thereon. Such notice is to be in writing and the university may require written acknowledgment of such provisions by any person working on internally sponsored projects. A summary of work for which university sponsorship limits the intellectual property rights of potential creators will be maintained by the Office of Sponsored Research and will be available to the general university community.

If the university fails to notify a creator, effectively and in advance, of limitations imposed on his intellectual property rights by internal university sponsorship, the creator is entitled to receive from the university 50% (fifty percent) of the net proceeds to the university resulting from his intellectual property.

3-3. Individual Agreements

Ownership Provisions: Intellectual property which is the subject of a specific agreement between the university and the creator(s) thereof shall be owned as provided in said agreement. Such agreements by the university and the faculty are encouraged.

Procedural Provisions: Except where limited by external sponsorship agreements, creators and the university may negotiate individual agreements to govern ownership of intellectual property regardless of the applicability of any other provision hereof.

3-4. Intellectual Property Created Within Scope of Employment

Ownership Provisions: Intellectual property created by university employees who were employed specifically to produce a particular intellectual property shall be owned by the university if said intellectual property was created within the normal scope of their employment. Faculty are presumed not to be hired to produce a particular intellectual property. On the other hand, computer programs written on the job by staff computer programmers would fall under this provision.

3-5. Public Dedication

Ownership Provisions: Except when limited by sub-parts 3-1, 3-2, 3-3 or 3-4 above, the creator of any intellectual property may choose to place his or her creation in the public domain. In such cases both the creator and the university waive all ownership rights to said property.

Procedural Provisions: Creators wishing to place their intellectual property in the public domain are responsible for ascertaining that the right to public dedication of that intellectual property is not limited by any external agreement, university sponsorship arrangement or terms of employment as described in Provisions 3-1, 3-2 or 3-3. The university provost will provide such a determination in writing upon request by the creator. It is also the creator's responsibility to ensure that disclosure does not include valuable intellectual property owned by others. (This provision does not release the university from its general obligation to notify creators of limitations to intellectual property rights specified in Provisions 3-1 and 3-2.)

To facilitate the actual transfer of knowledge of the intellectual property to the public at large, the creator shall provide the university with a complete description and documentation of the property placed in the public domain, specifically including a copy of the property in the case of printed material, and complete machine-readable source code in the case of software. All such material provided to the university will be placed in the University Library and made available to the public at large. The university will take appropriate action on a regular basis to publicize summary descriptions of intellectual property recently placed in the public domain. The university will also provide any member of the general public copies of such material on a cost-recovery basis.

The provisions of this section do not apply to the normal scholarly or creative publication processes unless the creator intends to waive all proprietary rights to the publication.

3-6. In General

Unless governed by sub-parts 3-1, 3-2, 3-3, 3-4 or 3-5 above, owner-ship of intellectual property created at the university shall be deter-mined as follows:

3-6-1. Traditional Rights Retained

Ownership Provisions: In keeping with academic traditions at the university, the creator retains all rights to the following types of intellectual property, without limitation: books (including textbooks), educational course-ware, articles, non-fiction, novels, poems, musical works, dramatic works including any accompanying music, panto-mimes and choreographic works, pictorial, graphic and sculptural works, motion pictures and other similar audio-visual works, and sound recordings, regardless of the level of use of university facilities. This provision does not include computer software (other than educational course-ware) or data bases.

Procedural Provisions: The types of intellectual property listed in the preceding paragraph share the attribute that they display information or visual or auditory appearances which are fully revealed to the purchaser or consumer. Thus, for example, source code listings would also be considered within this category. On the other hand, most computer software and data bases do not share this attribute; they are characterized by their capacity to perform tasks. Because of their utilitarian nature, ownership rights with respect thereto are governed by 3-6-3 or 3-6-4. Educational course-ware is included in this provision in all cases because of its role in furthering the primary educational mission of the university.

This provision applies regardless of any university sponsorship of the work, and it may be modified only by a specific prior agreement between the creator and the university. The use of university-owned computers and other facilities in the preparation of books and similar works does not alter this provision, though other university policies may limit such use or require reimbursement to the university. Similarly, the use of externally sponsored resources does not alter this provision, unless the creator is effectively notified in advance of such limitations to his rights in accordance with 3-1.

3-6-2. No Substantial Use of University

Facilities Ownership Provisions: The creator owns all intellectual property created without substantial use of university facilities, including intellectual property rights in computer software and data bases.

3-6-3. Substantial Use of University Facilities - No External or Internal Sponsorship

Ownership of intellectual property created with substantial use of university facilities, but not directly arising from externally sponsored work, or from work for which the university has declared itself as sponsor, shall be determined as set forth hereinafter depending on whether the creator or the university develops said property.

3-6-3-1. Development by Creator

Ownership Provisions: The creator originally owns intellectual property created with substantial use of university facilities but no external or internal sponsorship, and retains said ownership by commercial development of said property subject to the following:

(i) the university shall receive 15% (fifteen percent) of the net proceeds to the creator above $25,000 (twenty-five thousand dollars) in constant 1984 dollars from all sources (in the case of patents and copyrights, this provision shall be limited to the life of the patent or copyright), and

(ii) the university shall receive a perpetual, non-exclusive, non-transferable, royalty free license to use said intellectual property. In the case of software, this license includes access by specified university personnel to the source listings, and the university shall require each person to whom a disclosure is made to execute in advance a binding confidentiality agreement in favor of and enforce-able by the creator. If the intellectual property is created solely by a student or students, the creator is exempt from the obligation to pay to the university a fraction of his net proceeds, but not from the provision of this paragraph for a non-exclusive license to the university.

Procedural Provisions: If the creator develops an intellectual property that is covered by this provision, he must make full and fair disclosure to the university of all such sources of compensation relating to that intellectual property.

3-6-3-2. Development by the University

Ownership Provisions: When intellectual property is created with substantial use of university facilities, but not directly arising from sponsored research, the creator will originally retain the rights to the property, provided that he desires to commercially develop the property himself or to make it available to the public. If, however, the creator elects not to commercially develop same or fails to show diligence in pursuing such development, then the ownership rights to that property may be acquired by the university. Intellectual property acquired by the university in this fashion will be treated as in 3-6-4-1 below.

Procedural Provisions: At the time the intellectual property is disclosed to the university's provost as required under Section 4-1, or at any time thereafter, the university may request that the creator decide whether he will develop the intellectual property or will grant the rights to the university, and execute documents to pass on the title. Such a decision must be made within one year of the request or the creator will automatically lose his rights in favor of the university.

3-6-4. Substantial Use of University Facilities - External or Internal Sponsorship

Ownership of intellectual property created with substantial use of university facilities and directly arising from work sponsored under an agreement between an external sponsor and the university, or from work for which the university has declared itself a sponsor, but for which neither the external sponsor nor the university have specified the ownership of resulting intellectual property shall be determined as set forth hereinafter depending on whether the creator or the university develops said property.

3-6-4-1. Development by University

Ownership Provisions: The university originally owns intellectual property created with substantial use of university facilities provided by an external agreement or internal university sponsorship and retains said ownership by commercial development of said property, subject to the following: in all cases, the creator shall receive 50% (fifty percent) of the net proceeds to the university.

Procedural Provisions: When an intellectual property is created with substantial use of university resources provided by an external research contract or a specific university sponsorship agreement, and when that contract or agreement either does not specify the disposition of the intellectual property rights arising from that sponsorship, or it permits the university and/or creator to retain or acquire such intellectual property rights, the university will originally retain the rights to such intellectual property.

3-6-4-2. Development by Creator

Ownership Provisions: When intellectual property is created with substantial use of university facilities provided by external or internal sponsorship, the university will originally retain the rights to the property, provided that it desires to commercially develop the property or to make it available to the public. If, however, the university elects not to commercially develop same or fails to show diligence in such development, the ownership rights to that property may be acquired by the creator. Intellectual property acquired by the creator in this fashion will be treated as in 3-6-3-1 above. This assignment of rights to the creator may be prohibited by the terms of an external sponsorship agreement with the university or by an internal university sponsorship declaration, but in such cases the creator must be notified in advance, as in Provisions 3-1 and 3-2.

Procedural Provisions: At the time the intellectual property is disclosed to the university's provost as required by Section 4-1, or at any time thereafter, the creator may request that the university decide whether it will commercially develop the intellectual property or execute an assignment of the intellectual property rights to the creator. Such a decision must be made within 120 (one hundred twenty) days of the request or the university automatically waives its rights in favor of the creator, and it must execute an assignment of these rights to the creator.

3-6-5. Consulting Agreements

Ownership Provisions: Work done by individuals as consultants to outside firms is presumed not to involve unreimbursed substantial use of university facilities, and the rights to intellectual property created under consulting agreements are retained by the outside firms or the individual as specified by the terms of the consulting agreement and the terms of Provision 3-6-2 above.

Procedural Provisions: Under university policy consulting work must not make substantial unreimbursed use of university facilities except by explicit prior agreement. Any member of the university community who is engaged in consulting work or in business is responsible for ensuring that provisions in his agreements are not in conflict with this policy of the university or with the university's commitments. The university's Innovation Transfer Office will, upon request, provide assistance in this respect. The university's rights and the individual's obligations to the university are in no way abrogated or limited by the terms of such agreements. Each creator of intellectual property should make his obligations to the university clear to those with whom he makes such agreements and should ensure that they are provided with a current statement of the university's intellectual property policy. Appropriate sample contract wording to cover various possible external consulting arrangements shall be available from the university provost.

4. General Procedures

4-1.

The creator of any intellectual property that is or might be owned by the university under this policy is required to make reasonably prompt written disclosure of the work to the university's provost, and to execute any document deemed necessary to perfect legal rights in the university and enable the university to file patent applications and applications for copyright registration when appropriate. This disclosure to the provost should be made at the time when legal protection for the creation is contemplated, and it must be made before the intellectual property is sold, used for profit, or disclosed to the public. Whenever legal protection for intellectual property is anticipated all persons engaged in such creative activity are encouraged to keep regular notebooks and records.

4-2.

Whenever the university undertakes commercial development it shall do so, if possible, in a fashion that provides for the widest possible dissemination, avoiding suppression of inventions from which the public might otherwise benefit, providing for non-exclusive licensing at reasonable royalties, and giving consideration to more favorable or royalty-free licensing to non-profit charitable institutions, minority businesses or enterprises in developing countries.

4-3.

The university's share of any proceeds under this policy will be used to reimburse the university for its expenses for commercial development of intellectual property. Any additional return to the university will be used to further the academic purposes of all the disciplines of the entire university.

5. Resolution of Disputes

This policy constitutes an understanding which is binding on the university and on the faculty, staff, and students upon whom it is effective according to the terms of Section 6 below, as a condition for participating in research programs at the university or for the use of university funds or facilities.

Any question of interpretation or claim arising out of or relating to this policy, or dispute as to ownership rights of intellectual property under this policy, will be settled by the following procedure:

- The issue must first be submitted to the university's Intellectual Property Adjudication Committee in the form of a letter setting forth the grievance or issue to be resolved. The committee will review the matter and then advise the parties of its decision within 60 days of submission of the letter.
- If any of the parties to the dispute is not satisfied with the committee's decision, the party may seek binding arbitration in Pittsburgh, Pennsylvania and in accordance with the Rules of the American Arbitration Association then in effect. Judgment upon the award rendered by the arbitrator(s) may be entered in any court having jurisdiction thereof. The arbitrator(s) will give some weight to the decision of the Intellectual Property Adjudication Committee in reaching a decision. The losing party of the arbitration hearing will pay for all costs of the arbitration unless the arbitrator(s) specifies otherwise.

The Intellectual Property Adjudication Committee will consist of a chair who is a member of the tenured faculty, four other members of the faculty, and four other members representing, respectively, the university administration, the technical staff, and the graduate and undergraduate student bodies. Initially, half of the members of the committee (including the chair) will be appointed for two-year terms of office, and the remaining half will be appointed for a one-year term. After one year new members of the committee will be appointed for two-year terms of office. The chair will be appointed by the chair of the Faculty Senate, with the advice and consent of the Faculty Senate Executive Committee, and the remaining eight members of the committee will be appointed by the president of the university or his designee. At all times at least one of the faculty members will have had significant practical experience with intellectual property development and exploitation. The faculty members appointed by the president of the university will be selected from a list of nominees prepared by the Faculty Senate or its designated committee and nominees with experience in intellectual property development will be identified as such by the Faculty Senate. The staff representative will be selected from a list of nominees prepared by Staff Council, and the administration representative will be named directly by the president of the university or his designee. The graduate student representative will be selected from a list of nominees prepared by the Graduate Student Organization. The undergraduate representative will be chosen from a list of nominees prepared by the Student Senate. The committee will use the guidelines set forth in this policy to decide upon a fair resolution of any dispute.

If possible, the committee will also provide on request informal advisory opinions to creators and the university indicating how it is likely to interpret the provisions of this policy as it applies to special cases.

6. Effective Date of Policy

This policy will become effective August 27, 1985. Once effective this policy will be binding on new faculty, administration, and staff when hired, and on graduate and undergraduate students when admitted. Current faculty and staff will also become bound by this policy when they sign new employment contracts as the result of the renewal of limited-term appointments or promotion. Other university personnel, including tenured faculty, and current staff and students may choose to become bound by this policy for future and pending intellectual property by voluntary written consent. Unless the creator and the university agree to a different arrangement, intellectual property that is already partially developed at the time this policy becomes effective will be treated according to the provisions of the patent policy by which the University creator is currently bound. Similarly, members of the university working under contracts signed before the effective date of this policy who do not choose to accept this policy will remain bound by the patent policies that already apply to them. With respect to intellectual property developed during the course of employment at the university, this policy shall continue to be binding on any person whose relationship with the university becomes terminated. The university should take all administrative steps necessary to ensure that employees and students sign, upon initial employment, registration or at other appropriate times, forms that indicate their acceptance of this policy.

7. Amendments of the Policy

Amendments of this policy may be proposed by the Faculty Senate, Staff Council or university administration. Proposed amendments must be approved by a two-thirds majority of votes in the Faculty Senate and subsequently approved by a simple majority of votes cast in a referendum administered by the Faculty Senate that is open to all members of the faculty as defined by this policy and to the exempt staff, provided that this majority constitutes at least 25% (twenty-five percent) of those eligible to vote. This referendum must be preceded by an opportunity for public discussion open to all interested faculty, administration, staff and students. Amendments that are supported by the faculty and staff must then be approved by the president of the university and adopted by the university trustees. Once adopted, amendments will become binding on new faculty, administration, and staff when hired, on existing faculty and staff when they sign new employment contracts, and on graduate and undergraduate students when admitted. Other university personnel, including tenured faculty, and current staff and students may choose to become bound by this policy for future and pending intellectual property by voluntary written consent. Intellectual property that is already developed or under development at the time that an amendment to the policy is ratified will not be bound by the terms of the amendment without the voluntary written consent of both the creator and the university.

Footnote:

[1] This document presumes the existence of a university office to facilitate technology transfer. Such an office would serve as a clearinghouse for contacts with outside partners, would perform patent and copyright tasks, and would develop an effective marketing capability.

Policy on Student Privacy Rights

www.cmu.edu/policies/student-and-student-life/privacy-rights-students.html (https://www.cmu.edu/policies/student-and-student-life/privacy-rights-students.html)

Policy Statement

Under the Family Educational Rights and Privacy Act (FERPA), you have the right to:

- inspect and review your education records;
- request an amendment to your education records if you believe they are inaccurate or misleading;
- request a hearing if your request for an amendment is not resolved to your satisfaction;
- consent to disclosure of personally identifiable information from your education records, except to the extent that FERPA authorizes disclosure without your consent; and
- file a complaint with the U.S. Department of Education Family Policy Compliance Office if you believe your rights under FERPA have been violated.

1. Inspection

What are education records?

Education records are records maintained by the university that are directly related to students. These include biographic and demographic data, application materials, course schedules, grades and work-study records. The term does not include:

- information contained in the private files of instructors and administrators, used only as a personal memory aid and not accessible or revealed to any other person except a temporary substitute for the maker of the record;
- University Police records;
- employment records other than work-study records;
- medical and psychological records used solely for treatment purposes;
- records that only contain information about individuals after they have left the university; and
- any other records that do not meet the above definition of education records.

How do I inspect my education records?

- Complete an Education Inspection and Review Request Form (http://www.cmu.edu/hub/registration/docs/review-record.pdf) [PDF] (https://

www.cmu.edu/hub/docs/review-record.pdf) and return it to The HUB in order to notify the University Registrar's Office.

- The custodian of the education record you wish to inspect will contact you to arrange a mutually convenient time for inspection, not more than 45 days after your request. The custodian or designee will be present during your inspection.
- You will not be permitted to review financial information, including your parents' financial information, or confidential letters of recommendation, if you have waived your right to inspect such letters.
- You can get copies of your education records from the office where they are kept for 25 cents per page, prepaid.

2. Amendment

How do I amend my educational records?

- Send a written, signed request for amendment to the University Registrar, Carnegie Mellon University, A19 Warner Hall, Pittsburgh, PA 15213. Your request should specify the record you want to have amended and the reason for amendment.
- The university will reply to you no later than 45 days after your request. If the university does not agree to amend the record, you have a right to a hearing on the issue.

3. Hearing

How do I request a hearing?

- Send a written, signed request for a hearing to the University Registrar, Carnegie Mellon University, A19 Warner Hall, Pittsburgh, PA 15213. The university will schedule a hearing no later than 45 days after your request.
- A university officer appointed by the Associate Vice President & Director of Enrollment Services who is not affiliated with your enrolled college will conduct the hearing.
- You may bring others, including an attorney, to the hearing to assist or represent you. If your attorney will be present, you must notify the university ten days in advance of the hearing so that the university can arrange to have an attorney present too, if desired.
- The university will inform you of its decision, in writing, including a summary of the evidence presented and the reasons for its decision, no later than 45 days after the hearing.
- If the university decides not to amend the record, you have a right to add a statement to the record that explains your side of the story.

4. Disclosure

Carnegie Mellon generally will not disclose personally identifiable information from your education records without your consent except for directory information and other exceptions specified by law.

What is directory information?

Directory information is personally identifiable information of a general nature that may be disclosed without your consent, unless you specifically request the university not to do so. It is used for purposes such as compiling campus directories.

If you do not want your directory information to be disclosed, you must notify the University Registrar's Office in writing within the first 15 days of the semester.

Notifying the University Registrar's Office covers only the disclosure of centralized records. Members of individual organizations such as fraternities, sororities, athletics, etc. must also notify those organizations to restrict the disclosure of directory information.

Carnegie Mellon has defined directory information as the following:

- your full name
- local/campus address and local/campus telephone number
- email User ID (Andrew ID) and address
    - Please note: Andrew User IDs cannot be completely suppressed from our electronic systems. While it may be possible to suppress the association of an individual's name with their user id, doing so may adversely impact the delivery of electronic mail or other electronic services.
- major, department, college
- class status (freshman, sophomore, junior, senior, undergraduate or graduate)
- dates of attendance (semester begin and end dates)
- enrollment status (full, half, or part time)
- date(s) of graduation
- degree(s) awarded
- sorority or fraternity affiliation

For students participating in intercollegiate athletics, directory information also includes:

- height, weight
- sport of participation

What are the other exceptions?

Under FERPA, Carnegie Mellon may release personally identifiable information from your education records without your prior consent to the following individuals or organizations:

- school officials with legitimate educational interests (“School officials” are Carnegie Mellon employees in administrative, supervisory, academic or support staff positions; Carnegie Mellon trustees; individuals and companies with whom the university has contracted, such as attorneys, auditors, or collection agencies; and individuals assisting school officials in performing their tasks. School officials have a “legitimate educational interest” if they need to review an education record in order to fulfill their professional responsibilities.);
- certain federal officials in connection with federal program requirements;
- organizations involved in awarding financial aid;
- state and local officials who are legally entitled to the information;
- testing agencies such as the Educational Testing Service, for the purpose of developing, validating, researching and administering tests;
- accrediting agencies, in connection with their accrediting functions;
- parents of dependent students (as defined in section 152 of the Internal Revenue Service Code);
- individuals or organizations in order to comply with a judicial order or subpoena (after making a reasonable effort to notify the student in advance of compliance so that the student can take protective action, except in cases where the university is legally required not to disclose the existence of the subpoena);
- appropriate parties in a health or safety emergency, if necessary to protect the health or safety of the student or other individuals;
- officials of another school in which the student seeks or intends to enroll;
- victims of violent crimes or non-forcible sexual offenses (the results of final student disciplinary proceedings);
- parents or legal guardians of students under 21 years of age (information regarding violations of university drug and alcohol policies);
- courts (records relevant to legal actions initiated by students, parents or the university); and
- individuals or organizations in order to comply with federal laws concerning sex offenders and other individuals required to register under section 170101 of the Violent Crime Control and Law Enforcement Act of 1994.

5. Complaints

If you believe the university has not complied with FERPA, you can file a complaint with the:

Family Policy Compliance Office, Department of Education, 400 Maryland Avenue, S.W. Washington, DC 20202-4605

Note: Your Carnegie Mellon GUID (global user identification) number is also designated as directory information under FERPA, but does not contain personally identifiable information and therefore cannot be used by itself to determine your identity or to access your records.

Policy on Restricted Research

www.cmu.edu/policies/research/restricted-research.html (https://www.cmu.edu/policies/research/restricted-research.html)

Universities have two primary purposes: to create knowledge and to disseminate knowledge. Carnegie Mellon University recognizes the importance of open intellectual communication within a research group, within the university, and within the larger community outside. Ideally, all units of the university would disseminate the results of research as quickly and as widely as possible. Some members or units of the university, however, desire to do research that may be difficult or impossible without restrictions or without access to classified or proprietary materials.

There exists, therefore, a tension between the university's goal of disseminating knowledge freely and the desire on the part of some of its members to conduct restricted research on important problems. The university intends to guarantee the academic freedom of all faculty members to do research in their own manner on topics of their own choosing, provided that such research is consistent with the overall purposes of the university.

This policy seeks to resolve the tension between the desire to participate in restricted research and the desire to maintain the open atmosphere of the university by confining restricted research to semi-autonomous units, which are not associated with any academic departments. It thereby establishes the principle that restricted research is inappropriate at Carnegie Mellon University except in the semi-autonomous units.

This policy does not attempt to anticipate all possible concerns about restricted research. In some cases, decisions will need to be made about particular research projects to which the application of particular policy guidelines are not clear. In choosing to accept or decline such projects, the university will weigh the potential of a project for generating and disseminating new knowledge for the benefit of society, against the project's potential for adversely affecting the climate for research conducted in a free and open environment. While this policy sets no explicit limits on the extent of classified research permitted in the semi-autonomous units, it is not the intent of the policy to encourage any unit of the university to engage in classified research as a primary ongoing activity. Indeed, it is expected that classified projects will never represent more than a small fraction of the total research effort in any unit.

Definitions

Research: all projects and investigations involving the creation of new knowledge of a theoretical or practical nature. The term “research” as used here encompasses both “research” and “development” as they are commonly defined.

Classified research: research, the free dissemination of the results of which is deemed to jeopardize national security. The federal government controls access to the environment in which such research is performed, restricts discussions about the work in progress to individuals with clearance and a “need to know,” and limits publication of research, results or access to data needed to verify results, for a specified period of time.

Proprietary research: research that results in intellectual property that is owned by entities other than Carnegie Mellon University. Such entities may wish to market products derived from inventions or ideas that are developed at the university. They might, therefore, desire to fund projects which restrict access to data and to discussions about work in progress to individuals with a “need to know,” and to seek, for a specified period of time, a delay in publication of research results or data needed to verify results. Such entities may also provide access to proprietary material, which researchers must agree not to include in publications.

Publication: oral or written dissemination.

Restricted research: includes all classified research, and any proprietary or other research that requires more than a six month delay in publication of the research results.

Semi-autonomous units: units of the university specifically so designated by the president, after consultation with the URC and the Faculty Senate, currently the Mellon Institute and the Software Engineering Institute.

Non-autonomous units: all university entities other than semi-autonomous units.

Restricted Research in Non-Autonomous Units

It is the policy of Carnegie Mellon that restricted research is inappropriate and, therefore, not permitted within its non-autonomous units.

It is also the policy of Carnegie Mellon not to permit involvement of students in projects which carry restrictions that may impede their progress toward a degree. Therefore, students should not be involved in contracts that require the delay of a student's publication of research results when such results are intended for use in obtaining academic credit, except that a sponsor may require a delay of thirty days for review of publications for removal of proprietary information that was provided by the sponsor for the conduct of the research.

Proprietary research is allowed within non-autonomous units provided it is subject to limitations (excluding students' publications as noted above) no more stringent than the following:

- A sponsor may request a delay of up to six months in publication so that steps may be taken to secure intellectual property rights to inventions or ideas developed under the contract.
- A sponsor may require a delay of thirty days for review of publications for removal of proprietary information which was provided for the conduct of the research.

Considerations for faculty/researchers:

The university recognizes that problems arise in both restricted research and research that is not itself restricted but that involves access to classified or propriety information or materials (hereinafter, restricted materials). Researchers may also have access to restricted materials when serving as consultants. Access to restricted materials gives rise to concerns about limitations on researchers' freedom to communicate. In such instances, researchers must exercise consider-able judgment to conduct their research in an open environment while protecting the restricted materials to which they have access. Researchers must also be aware that the university will judge their performance as researchers through their publications or through other scholarly products that arise from their research. Research that is restricted in dissemination, or not available for public review, cannot be considered in promotion or reappointment decisions or in evaluations of academic performance of any kind.

Considerations for faculty/researchers:

There are important concerns about the involvement of students in restricted research. It is necessary for students to publish their work in order to obtain degrees, course credit and professional recognition. Students rely to a large degree on their faculty advisor's judgment for guidance and advice. Research that is restricted in dissemination, or not available for public review, cannot be used for academic credit. Thus, before working on such research, a student must be notified in writing that work on this research may not be used for academic credit.

Restricted Research in Semi-Autonomous Units

The semi-autonomous units associated with Carnegie Mellon may conduct restricted research.

Faculty members may conduct restricted research in or in cooperation with semi-autonomous units only on a consulting basis or by means of a formal, internal leave of absence from their non-autonomous units.

Work that is restricted in any way may not be used for academic evaluations until it is released for publication, and then only with respect to future academic actions.

Students may occasionally be employed by the semi-autonomous units, provided that such employment does not interfere substantially with progress toward a degree. However, they must be made aware that work that is restricted cannot be used for academic credit. Work that was restricted and is later released for dissemination and review can be applied toward future academic credit. Students should be discouraged from working on restricted research in which dissemination may be delayed indefinitely.

Guidelines for all Units

Work by students on restricted research projects shall not be made a condition for admission or financial aid.

The principal investigator is responsible for informing all members of a project (faculty, staff and students) of any restrictions imposed on the dissemination of information related to the research. This must be done prior to the start of the project or prior to an individual joining an existing project.

Restrictions on access to university facilities due to the conduct of restricted research must be kept to a minimum. Access to and movement through the facilities in which restricted research is conducted must be consistent with standard university procedures.

The Provost's Office is responsible for obtaining signed documents from principal investigators on restricted research projects attesting that they are aware of all restrictions imposed on the research and that they have informed all participants of these restrictions.

The Office of Sponsored Research shall review all proposals and contracts prior to approval for conformity with these guidelines. Any that do not meet these guidelines will be referred to the University Research Council (URC) for review and recommendation of appropriate action to the provost.

To maintain a balance with the university's goals of broad dissemination of knowledge, the URC will conduct an annual review of all restricted research being conducted at the university. This review will be made based on a listing of all contracts that involve restricted research. This listing shall include the title and sponsor(s) of the research, name(s) of principal investigator(s), and the amount of funding of each contract.

The university community will be informed annually, through the URC's written report to the Faculty Senate and Student Senate, of the nature and overall impact of restricted research at Carnegie Mellon.

Existing sponsored research projects shall be allowed to continue under the terms of their present contract. However, renewal contracts must conform with this policy.

Student Activities Fee

www.cmu.edu/policies/student-and-student-life/activities-fee.html (https://www.cmu.edu/policies/student-and-student-life/activities-fee.html)

By action of the Board of Trustees, a required Student Activities Fee in addition to tuition is charged to all under-graduate students and graduate students who enroll for 19 units or more. Student Government is responsible for administering the fee and for using it only for the support of projects under the following guidelines:

1. Activities and facilities which can be described as meeting the reasonably predictable social, cultural, recreational, or welfare needs of college students.
2. Publications which can reasonably be presumed to serve the needs of the student community for communication, expressions of opinion, and the conduct of their business.
3. Such enterprises of an entrepreneurial nature undertaken by the student body as can reasonably be expected to serve as an instrument for meeting the needs described above.

All functions and services provided by the fees described above must be in accordance with Carnegie Mellon's policy of non-discrimination. In addition, no use of such fees may be intended to violate or circumvent the policies of the university or the laws of the land.

Final responsibility for establishing the amount of any required fee rests with the Board of Trustees, which will consider changes only upon requests of the Student Government and the officers of the university.

Note: Historically, the Student Government has dedicated a specific portion of graduate students' activities fees to the Graduate Student Assembly to be used at their discretion.

Policy on Temporary Emergency Closing of the University

www.cmu.edu/policies/safety-and-security/emergency-closing.html (https://www.cmu.edu/policies/safety-and-security/emergency-closing.html)

Policy Statement

Carnegie Mellon University has an important commitment to students, parents, sponsors, benefactors and the community. Accordingly, the university will make every attempt to operate normally during severe weather or other emergencies. This includes holding classes, conducting research programs, and operating facilities and services. The university will attempt to operate normally unless such operation represents a clear danger to students, staff or faculty.

There may be occasions when the university community is served best by suspending normal operations. In that event, only the president (or the president's designated representative) has the authority to close the university and to specify those persons or group of persons who are free to leave or refrain from coming to campus. Staff members who provide primary services, including certain members of Physical Plant, Dining Services and Security, may be asked to work.

Standard Operations

Unless the president announces that the university is closed, everyone is expected to be at work as usual. When the university is in session, faculty members are expected to meet their scheduled classes and other obligations. If a faculty member is unable to meet a scheduled class, he or she should notify the department office and arrange either for a qualified substitute or for a future make-up session.

If the university is open but a staff member is unable to come to work because of severe weather or other emergency, he or she should notify the supervisor as soon as possible. Staff members will be expected to make up lost time or use Paid Time Off (PTO), consistent with regular operating protocols.

Announcement of Closing

As soon as the president or designee determines that the university must be closed, University Relations will alert local radio and television stations. Also, announcements of closings will be posted on the Carnegie Mellon electronic bboard official.cmu-news.

Contact

Questions concerning this policy or its intent should be directed to the Office of the President at 412-268-2200.

Student Leaves & Returns

Student Leave Policy

www.cmu.edu/policies/student-and-student-life/student-leave.html (https://www.cmu.edu/policies/student-and-student-life/student-leave.html)

Students must sometimes interrupt their studies for a variety of reasons (financial, academic or personal). Students choosing to take a leave of absence must first contact their department advisor to discuss their plans while on leave to work out any conditions that may be necessary for a smooth return to Carnegie Mellon.

A student may leave Carnegie Mellon by either withdrawing from the university (this means leaving the university with no intention of returning) or by taking a leave of absence (this means leaving the university temporarily, with the firm and stated intention of returning).

A Leave of Absence Form must be completed by all students requesting a leave of absence. A Withdrawal Form must be completed by all students who are withdrawing. Notifying instructors or no longer attending classes does not complete the process. Forms and related documentation are available on The HUB website (https://www.cmu.edu/hub/registrar/leaves-and-returns/). Not completing the leave form results in tuition being charged to the midpoint of the semester or the last date the student attended an academically-related activity such as an exam, tutorial or study group, or the last day a student turned in a class assignment.

Students are required to fill out all information on the form, including all comment sections relating to reasons for their leave of absence. After completion of the form, students must take it to their home department and dean's office for appropriate signatures. The process of taking a leave will not be complete until all necessary signatures are on the leave form. Under certain circumstances, students may also need the Dean of Student Affairs to sign off on the leave form. International students who are here on a F1 or J1 visa must consult the Office of International Education for information on possible visa implications prior to going on leave.

Students on leave are not permitted to live in university housing, attend classes or maintain employment as students at Carnegie Mellon while their leave is in effect.

Doctoral candidates in ABD (All But Dissertation) status who wish to take a leave of absence should refer to the Doctoral Student Status policy (https://www.cmu.edu/policies/student-and-student-life/doctoral-student-status.html).

Leaves during the academic semester will take effect as of the date signed by the student's dean. After the Leave of Absence or Withdrawal Form is received by the University Registrar's Office, it will be reviewed for the appropriate tuition refunds (see T (p. 14)uition Adjustment Policy (p.)) and grade implications. The recording of student courses and grades for taking a leave in a semester follows the deadlines for semester or mini courses, as follows:

- On or before the university deadline to drop classes with W (withdrawal) grades: all courses or grades are removed.
- After the university deadline to drop classes but before the last day of classes: W (withdrawal) grades will be assigned to all classes. (W grades apply to all undergraduate students; and graduate students in the College of Engineering, Heinz College, Mellon College of Science, and the Tepper School of Business.)

- After the last day of classes: Permanent grades assigned by the instructor will be recorded.

Student Return Policy

www.cmu.edu/policies/student-and-student-life/return-student.html (https://www.cmu.edu/policies/student-and-student-life/return-student.html)

Students on leave wishing to return to Carnegie Mellon to resume their degree studies may do so under several conditions. In order to be considered for return from leave (https://www.cmu.edu/hub/registrar/leaves-and-returns/), a student must first obtain an Application for Return form from The HUB or their academic department. This application requires information from the student regarding the intended semester of return, current address information and information about their leave. This application must be submitted to their home department at least one month prior to the beginning of the semester.

Undergraduates may return within their same academic department within two years. After two years, students returning in the same academic department are subject to space constraints and academic performance review. Graduate students must negotiate their return with their home department and must follow their department policy.

The Application for Return requires approval of the student's academic department and dean. If a student's department chooses to deny the student's Application for Return, the student may appeal to their dean. Any constraints governing the student's eligibility to return will be specified directly on the application by the academic department and/or dean's office or the Office of Student Affairs.

Students who have taken courses elsewhere must submit an official transcript and course descriptions with their Application for Return. Transfer credit approval is determined by the academic department based on course level, performance and appropriateness to the student's curriculum requirements. Credit transfer is subject to college-specific policy. Failure to submit the necessary documents at the time of return will result in denial of transfer credit.

The process of returning is not completed until all necessary signatures on the Return form are obtained by the student and until all outstanding bills are paid. The University Registrar's Office will then notify the appropriate university offices of the student's return.

Tuition Adjustment Policy

www.cmu.edu/policies/student-and-student-life/tuition-fees-adjustment.html (https://www.cmu.edu/policies/student-and-student-life/tuition-fees-adjustment.html)

Application

This policy applies to withdrawals and leaves of absence by all students (graduate, undergraduate, non-degree) for all semesters (Fall, Spring, Summer 1, Summer 2, Summer All).

Official Date of Withdrawal/Leave of Absence

For students who notify the university of their intent to withdraw or take a leave of absence, the official date of withdrawal or leave of absence is the earliest of:

- the date the student began the withdrawal or leave of absence process;
- the date the student notified their home department;
- the date the student notified the associate dean of their college; or
- the date the student notified the Dean of Students.

For students who do not notify the university of their intent to withdraw or take a leave of absence, the official date of withdrawal or leave of absence is:

- the midpoint of the semester;
- the last date the student attended an academically-related activity such as an exam, tutorial or study group, or the last day a student turned in a class assignment.

Tuition Adjustment

Students who withdraw or take a leave of absence before completing 60% of the semester will be charged tuition based on the number of days completed within the semester. This includes calendar days, class and non-class days, from the first day of classes to the last day of final exams. Breaks that last five days or longer, including the preceding and subsequent weekends, are not counted. Thanksgiving and Spring Break are not counted.

There is no tuition adjustment after 60% of the semester is completed. No tuition is charged to a student who is administratively withdrawn. See The HUB website (https://www.cmu.edu/sfs/tuition/adjustment/) for the complete tuition assessment schedule for the current semester.

Housing, Dining Plan & Fee Adjustments

Housing charges are adjusted daily, beginning on check-in day and ending on the last day of final exams for the semester. Holiday breaks are included; however, the Winter Break period is not included.

Dining plan charges are adjusted per the bi-weekly period. PlaidCash is assessed based upon actual use.

There is no adjustment of the Transportation Fee, Technology Fee or Student Activity Fee.

Financial Aid Adjustment

Federal and institutional financial aid is adjusted on the same basis as tuition. A student earns 100% of their federal or institutional financial aid when 60% of the semester is completed.

State grants and non-federal outside scholarships are adjusted based upon the withdrawal policy of the agency awarding the funds.

Contact

Questions concerning this policy or its intent should be directed to The HUB at 412-268-8186.

Financial Aid Policy Statement

www.cmu.edu/policies/student-and-student-life/financial-aid-statement.html (https://www.cmu.edu/policies/student-and-student-life/financial-aid-statement.html)

University Academic Scholarship Renewals

Carnegie Mellon University awards academic scholarships as part of the first-year financial aid process. Each of these scholarships is renewable for four academic years of study (five for architecture) based upon the maintenance of a specific cumulative quality point average. The academic scholarship renewal criteria are included in the scholarship notification letter which is mailed to the student prior to the May 1 matriculation deadline.

Each scholarship recipient's cumulative quality point average is reviewed at the end of each academic year. If the student achieves the scholarship renewal criteria, then the scholarship is automatically renewed for the next academic year.

If the student does not meet the cumulative quality point average requirement for renewal, then they are given the opportunity to appeal. A merit scholarship appeal form and instructions are automatically sent to the student at the end of each academic year.

The student's completed appeal form is reviewed by Student Financial Services. Input from the Associate Dean of the student's college is also considered. The student is notified, in writing, of the decision. The decision may be to renew the scholarship for the entire academic year, renew the scholarship for one academic term, or to reject the appeal. If the appeal is rejected, a written explanation is provided to the student.

Undergraduate Tuition Exchange Programs

Carnegie Mellon University assesses the standard tuition charge for the undergraduate tuition exchange programs.

Since Carnegie Mellon assesses the tuition charge, the student can be considered for all forms of institutional, state, and federal aid for which the student may have eligibility with the exception of any student employment program.

Undergraduate Study Abroad Programs

Carnegie Mellon University does not assess the tuition charge for any of the Study Abroad Programs.

Since Carnegie Mellon does not assess the tuition charge, the student is not considered for any institutional grants and scholarships. However, Carnegie Mellon will consider any student participating in an approved Study Abroad Program for all state and federal student aid programs for which the student may have eligibility with the exception of any student employment program.

The U.S. Department of Education and Carnegie Mellon University define an approved Study Abroad Program as one which is part of a contractual agreement between Carnegie Mellon and the host institution. Additionally, courses taken in the Study Abroad Program must be accepted for transfer to Carnegie Mellon by the Dean of the student's college.

Undergraduate Sponsored Study Abroad Programs

Carnegie Mellon assesses full tuition charges and all applicable fees to students participating in an undergraduate sponsored study abroad program.

Undergraduate International Students

Documentation Eligibility (U.S. Citizenship or Eligible Non-citizen)

You must be a U.S. Citizen or permanent resident alien to receive federal student aid. If you are a U.S. Citizen, but were not born in the United States, valid documentation includes a copy of your passport or naturalization certificate.

If you are a U.S. permanent resident alien or refugee, acceptable forms of verification include a photocopy of both sides of your I-551 or I-551C card.

Undergraduate international students are ineligible to receive any federal or state student financial aid. Additionally, Carnegie Mellon does not award any institutional financial aid funds to undergraduate international students.

Undergraduate Course Meeting Policy

www.cmu.edu/policies/student-and-student-life/ug-course-meeting.html (https://www.cmu.edu/policies/student-and-student-life/ug-course-meeting.html)

No undergraduate classes, exams, academic, or artistic activities (including: extra help session, rehearsals, ROTC drill, make-up exams, etc.) are scheduled on weekdays between 4:40 p.m. and 6:40 p.m. Extra class time beyond those regularly scheduled must take place either before 4:40 p.m. or after 6:40 p.m.

Undergraduate Course Meeting Procedure

This policy is not intended to reduce the rigor or vigor of the academic or artistic programs, but to ensure that students have a period in which they are free to carry on co-curricular activities and athletics. Scheduling classes, exams, or other academic and artistic activities makes it very difficult for the students to meet these commitments. Since we are all concerned about the quality of life at the university, this time must be held for the students.

In planning the academic course schedule, the University Registrar's Office will review all courses to ensure that no academic or artistic courses be scheduled in this period. In addition, any requests to schedule additional or makeup course meetings, review and/or study sessions, teaching assistant office hours, or other course-related meetings, must take place either before 4:50 p.m. or after 6:50 p.m. This includes meetings in all university spaces, not just within University Registrar's Office-controlled classrooms.

As with any policy, there must be a means of making exceptions. Any academic or artistic activities which you feel must be scheduled between 4:50 p.m. and 6:50 p.m. must be cleared with the University Registrar. These requests must be in writing either as a memo or through email. All requests must include the course relationship, intent for the requested meeting, and the reason why the meeting cannot be held either before 4:50 p.m. or after 6:50 p.m.

Any further clarification of this policy can be addressed to the Vice Provost for Education.

University Services

Carnegie Mellon University provides many services to students to help them thrive on and off campus, and in and out of the classroom. The university's service-oriented departments and offices focus on executing critical administrative functions to provide daily services to students, families, the campus community, and visitors. Listed below are some of the services offered by the university.

Academic Advising

University Statement on Academic Advising

Carnegie Mellon University commits to support excellence in academic advising. Even with the university's diverse offerings, a cohesive academic advising approach can directly impact the educational success of every undergraduate and graduate student. High quality advising rests upon (1) robust central resources, (2) discipline specific variations at the college- and program-levels, (3) skilled academic advisors of all types, and (4) engaged, committed students.   By conceptualizing advising as an ecosystem, CMU creates an environment that fosters long-term outcomes that benefit students while studying at CMU as well as making a difference as lifelong alumni.

The Advising Ecosystem at CMU

Goals

The advising ecosystem centers attention on the growth and development of CMU students while they are enrolled and beyond.   Excellent advising is as varied as our disciplines and students; yet, centralized standards, systems, and resources must connect seamlessly so that students make well-informed decisions. Advisors are supported in their work allowing for professional growth, intellectual satisfaction, and institutional recognition.

The ideal advising experience at CMU should reflect qualities of the academic environment: integrated, collaborative, innovative and data-driven. From guiding the transition into the university, movement through the curriculum, and exploration of careers or post-graduate studies, the advising ecosystem supports students in utilizing resources and setting and achieving their goals.

The CMU advising ecosystem seeks to facilitate:

- Goal setting and planning
- Leveraging support network
- Accessing resources
- Understanding policies
- Planning for career and post-graduation

advising practice, tools, and strategies

In order to realize our vision of excellent advising, CMU invests in an advising ecosystem that includes a host of resources and strategies designed to engage and facilitate students' academic and personal development.

- Adequate advising staffing and resources within each department/program
- Advisor training and professional development`
- Intentional focus on student success
- Collaboration to support student success
- Implement technology
- Contribute to career planning goals

student engagement in advising

Based on research at the national level and years of experience working with CMU students, the CMU advising ecosystem is designed to facilitate student behaviors that are proven to lead to success at the university. By engaging with the broad range of advising resources and student success strategies, students are expected to exhibit these behaviors indicating that they are on the path to successfully complete their degree requirements and attain personal development goals.

- Set goals and plan
- Engage the CMU support network
- Access resources
- Know and follow the rules
- Oriented towards the future

STUDENT outcomes

By engaging with the advising at CMU advising, students have opportunities and resources to exhibit the success behaviors outlined above. By conceptualizing advising as an ecosystem, CMU is creating an environment that fosters these long-term outcomes that benefit students both while they are students at CMU as well as lifelong alumni.

As a result of being advised at CMU, students are able to:

- maintain good academic standing in the university,
- feel a sense of belonging and inclusion within the university and their department,
- have individual and supportive relationships with their advisors and professors,
- maintain adequate progress toward completing their degree,
- find employment or further education directly related to their education plan or degree program after graduation; and
- use the skills and knowledge they have gained at Carnegie Mellon University to advance their professional and personal goals after leaving the university.

Computing Services

Stan Waddell, *Vice President for Information Technology & Chief Information Officer*
Location: Cyert Hall 285
Phone: 412-268-4357
it-help@cmu.edu
www.cmu.edu/computing (http://www.cmu.edu/computing/)

Computing Services maintains and supports computing resources for the campus community, including the campus wired and wireless networks, public printing, computer labs, email and software catalog.

Visit the Computing Services (http://www.cmu.edu/computing/) website to explore the services available to you, including how to:

- secure your devices
- connect to the network
- collaborate with your group
- access software
- manage your email
- use public printers and computer labs.

For help with these services, contact the Computing Services Help Center at 412-268-4357 (HELP) or it-help@cmu.edu.

Disability Resources & Equal Opportunity

Catherine Getchell, *Director of Disability Resources*
Location: Margaret Morrison Plaza, A30, 5136 Margaret Morrison St., Pittsburgh, PA 15213
Phone: 412-268-6121
access@andrew.cmu.edu
www.cmu.edu/disability-resources (https://www.cmu.edu/disability-resources/students/)

Disability Resources provides responsive and reasonable accommodations to students who self-identify as having a disability, including physical, sensory, cognitive and emotional disabilities. Through our office, the university can provide guidance, support services and accommodations to ensure that all students, regardless of ability, have equal access to the world-class education, campus programs and activities offered by CMU. We work to ensure that qualified individuals receive reasonable accommodations as guaranteed by the Americans with Disabilities Act (ADA) and Section 504 of the Rehabilitation Act of 1973.

Students are also welcome to discuss concerns about support for disabilities with members of the admission staff, housing office and/or health/ counseling and psychological services. Upon enrollment, students with disabilities should contact the Office of Disability Resources to discuss their needs and to develop a Student Individual Accommodation Plan. Accommodations are made with the intent to maintain the academic integrity of each course and the academic program as a whole, while also meeting assessed needs.

Equal Opportunity / Affirmative Action Policy

Carnegie Mellon is committed to equal employment opportunity for all and to affirmative action. Diversity is a source of strength for Carnegie Mellon and affirmative action is one of the tools that we use to achieve and sustain diversity. All personnel actions are administered in accordance with the university's commitment to non-discrimination and in compliance with applicable federal, state and local laws, statutes, orders and regulations. View the University Policy on Equal Employment Opportunity / Affirmative Action (https://www.cmu.edu/policies/administrative-and-governance/equal-opportunity-affirmative-action-ada.html).

Honor Societies

Phi Beta Kappa Society

Carnegie Mellon shelters a chapter of the Phi Beta Kappa Society, sponsored by the three colleges (Dietrich College of Humanities and Social Sciences, Mellon College of Science, and the School of Computer Science) that comprise the University's “arts and sciences” equivalent. The chapter's name is “Upsilon of Pennsylvania,” and was formally installed in April of 1995.

Founded in 1776 at the College of William and Mary in Williamsburg, Va., Phi Beta Kappa is the nation's oldest honorary society, with chapters at 276 of the foremost institutions of higher education across the country. Almost all members are elected by the chapters from among candidates for degrees in liberal arts and sciences, usually from the top 10% of the graduating class.

Membership in Phi Beta Kappa key has become a universally recognized mark of academic achievement in the liberal arts and sciences. The key's venerable pointing finger proclaims for all to see the wearer's commitment to Phi Beta Kappa's ancient principles (represented in the three stars) — friendship, morality and learning. The society's name is formed by the first letters of the phrase *Philosophia Biou Kybernetes*, Philosophy (wisdom) is the Guide of Life. In line with the conviction that the test of education lies not in what people know but in what they are, the objectives of humane learning encouraged by Phi Beta Kappa include not merely knowledge but also intellectual honesty and tolerance, a broad range of intellectual interests and understanding.

The Carnegie Mellon chapter is active in sponsoring visiting speakers, on-campus roundtables that focus on current issues, community service activities, scholarship opportunities, student research involvement, and the like.

The Honor Society of Phi Kappa Phi

The Honor Society of Phi Kappa Phi has been an important presence on campus since 1933. Phi Kappa Phi, a national honor society that began in 1897 at the University of Maine, takes its name from the initial letters of its adopted motto, Philosophia Krateito Photon, “Let the love of wisdom rule humanity.” Phi Kappa Phi recognizes and honors persons of good character who have excelled in scholarship, in all fields of study. Members are nominated by their department or their school or college and then invited to join the society.

To be eligible, seniors must be in the top ten (10) percent of their class and juniors in the upper seven and one-half (7.5) percent of their class at the time of invitation. Graduate students, alumni, faculty and staff are also eligible for nomination. The chapter inducts new members once a year, each spring, and provides information to its members on all sorts of opportunities, including study abroad, internships, and graduate fellowships, recognition and awards.

Office of Undergraduate Research and Scholar Development

Undergraduate Research

Richelle Bernazzoli, *Director of Undergraduate Research and Scholar Development*
Location: Cyert Hall A64, 5000 Forbes Ave., Pittsburgh, PA 15213
Phone: 412-268-5702
Fax: 412-268-6159
Email: bernazz@andrew.cmu.edu
www.cmu.edu/uro (http://www.cmu.edu/uro/)

At Carnegie Mellon, undergraduates are building mobile robots, creating documentary films, investigating cultural trends, and developing new digital communication technology. These student researchers find themselves in the heart of the university intellectual community, where they discover the thrilling (and often messy) process of creating new knowledge.

We use a broad definition of research that includes appropriate activities in the arts and humanities, and social sciences, as well as the sciences and technical fields: "Research, scholarly, or artistic activities that lead to the production of new knowledge; to increased problem solving capabilities, including design and analysis; to original critical or historical theory and interpretation; or to the production of art or artistic performance."

The Office of Undergraduate Research and Scholar Development supports student research in every field of study. We give SURG grants (https://www.cmu.edu/uro/academic-research/SURG/) to cover research expenses; Fellowships (https://www.cmu.edu/uro/summer%20research%20fellowships/SURF/#surf) and Apprenticeships (https://www.cmu.edu/uro/summer%20research%20fellowships/sura/) for full-time summer research and part-time academic year research (https://www.cmu.edu/uro/academic-research/huray/); and Presentation Awards (https://www.cmu.edu/uro/PresAward/#pres) to support students presenting at academic conferences. In May of each year, we hold our campus-wide celebration of undergraduate research, the Meeting of the Minds (https://www.cmu.edu/uro/MoM/#MoM).

How can we help?

- **Advising:** We meet with students to discuss how best to move forward on their interests and engage in undergraduate research at Carnegie Mellon
- **Workshops:** We offer writing workshops each semester to assist students in the proposal writing process
- **Research Development:** Each of our programs comes with complementaryy workshop instruction in researcher development topics, such as communicating your research, building a research network, and understanding research design.

National and International Fellowships and Scholarships

Location: Cyert Hall A64, 5000 Forbes Ave., Pittsburgh, PA 15213
Phone: 412-268-9987
Fax: 412-268-6159
Email: fso-general@andrew.cmu.edu
www.cmu.edu/ (http://www.cmu.edu/uro/)fso (https://www.cmu.edu/fso/)

The Office of Undergraduate Research and Scholar Development works with current Carnegie Mellon undergraduate and graduate students, as well as alumni, in fulfilling their intellectual and professional goals by pursuing nationally competitive scholarships and fellowships. We promote awareness of external scholarship and fellowship opportunities, advising, writing support, overall management of the process, and interview preparation.

For information about fellowships and scholarships related to financial aid, please visit Student Financial Services (https://www.cmu.edu/sfs/financial-aid/) website.

What are fellowships and scholarships?

Fellowships and scholarships are competitive, merit-based monetary awards that support a wide range of purposeful activities. These include research, internships, projects, and study abroad.

Who is eligible?

Eligibility depends on the particular award. More detail is available in the descriptions and links to each award.

How do I get started?

Read through the award descriptions on our website (https://www.cmu.edu/fso/) and make a list of which you'd like to pursue. Then make an appointment (https://forms.gle/avfFZcSyt1ycoh9f8/) with a representative.

Student Academic Success Center

Renee Camerlengo, *Executive Director*

Location: Posner Hall, 1st and 2nd floors
Phone: 412-268-6823
www.cmu.edu/student-success (https://www.cmu.edu/student-success/)

The Student Academic Success Center focuses on creating spaces for students to engage in their coursework and approach to learning through many group and individual program options. The team supports student success by providing academic coaching, subject-specific tutoring, effective communication strategies, accommodations for students with disabilities, language support for multilingual learners and initiatives that coordinate holistic academic support. They also engage with faculty and with staff to improve the coordination and professional development for academic advisors.

Teacher Certification

Carnegie Mellon offers a teacher certification program in the school of music but does not offer a degree in education or teacher certification program in other academic areas. Students can take relevant classes through several departments on campus to develop skills and knowledge that will help them to prepare for a career in K-12 education. There are several pathways to a teaching career and interested students can reach out to the Leonard Gelfand Center (https://www.cmu.edu/gelfand/contact-us.html) to discuss opportunities and programs that can be pursued.

University Libraries

Keith Webster, *Helen and Henry Posner, Jr. Dean of University Libraries and Director of Emerging and Integrative Media Initiatives*
Location: Hunt Library, 4909 Frew St., Pittsburgh, PA 15213
Phone: 412-268-2444
www.library.cmu.edu (http://www.library.cmu.edu)

The University Libraries is your partner in discovery, here to get you what you need so you can move faster on the path to your goals. Offering access to extensive resources, study spaces, research support, and low-stakes learning opportunities, CMU's librarians enrich the student experience by providing support, expertise, tools, and training. You bring the inspiration, we'll find the information.

Access a Wealth of Information and Get Support at Every Stage of the Research Process

From the Libraries' home page (www.library.cmu.edu (http://www.library.cmu.edu/)):

- Find (https://www.library.cmu.edu/find/#catalog): The library catalog is your one-stop, no-cost shop for access to journals, books, newspapers, databases, technology, and tools. Search by course reserves if your instructor has reserved materials for your class.
- Get Research Help – Access topic-specific research guides (https://guides.library.cmu.edu/), connect with a research specialist (https://www.library.cmu.edu/services-overview/librarian/), or set up a consultation (https://www.library.cmu.edu/services-overview/research-assistance/#schedule) about a research tool or method. Help is available however you need it: in-person, online, via email or chat.
- Services Directory (https://www.library.cmu.edu/services/): Information on library services and support, from data and code (https://www.library.cmu.edu/services/data-code-support/) and GIS (https://www.library.cmu.edu/services/gis/) to Bloomberg Terminals open science (https://www.library.cmu.edu/services/open-cmu/), and open source (https://www.library.cmu.edu/services/ospo/).
- Workshops (https://www.library.cmu.edu/services/workshops/) – Curious about the command line, data visualization, arts entrepreneurship, or prompt engineering? Libraries workshops are open to all and cover these topics and much, much more.
- Distinctive Collections (https://www.library.cmu.edu/distinctive-collections/): Discover the unique and rare collections housed only at CMU, from first editions of Galileo and eighteenth-century calculating machines to records on Artificial Intelligence from pioneers such as Herbert Simon and Allen Newell.

University Police

Aaron V. Lauth, *Chief*
Location: 4551 Filmore Street, Pittsburgh, PA 15213
campuspd@andrew.cmu.edu
www.cmu.edu/police (http://www.cmu.edu/police/)

The Carnegie Mellon University Police Department provides police services 24 hours a day, seven days a week, 365 days a year. Police officers are responsible for patrolling all university owned or leased property. In addition to patrol, officers will respond and investigate crimes and other emergencies that are in progress or have already occurred.

The success of the Patrol Unit is largely dependent on the eyes and ears of the community it serves. Immediate notification facilitates a rapid response. All emergencies on campus, including fire and medical, should be reported immediately to University Police. If you see suspicious activity or a crime in progress, call the University Police immediately by calling 412-268-2323.

Students are responsible for their personal property as well as the property of groups to which they belong. Insurance against loss, theft, or damage to such property occurring in the residence hall or elsewhere on campus must be arranged for by students or their parents through an insurance agent.

University Police makes available on its website a wide range of information about the university's security practices. View more information about the shuttle and escort service, community outreach, current investigations, crime prevention and safety education, and other programs and services by visiting www.cmu.edu/police (https://www.cmu.edu/police/).

Carnegie Mellon University publishes an annual campus security and fire safety report describing the university's security, alcohol and drug, sexual assault and fire safety policies, and containing statistics about the number and type of crimes committed on the campus, and the number and cause of fires in campus residence facilities during the preceding three years. You can obtain a copy by contacting the Carnegie Mellon Police Department at 412-268-2323. The annual security and fire safety report also is available online at www.cmu.edu/police/annualreports (https://www.cmu.edu/police/annualreports/).

Athletics and Physical Education

Josh Centor, Associate Vice President of Student Affairs and Director of Athletics, Physical Education & Recreation
Location: Skibo Gymnasium, Tech and Frew Streets, Pittsburgh, PA, 15213
Phone: 412-268-1236
jcentor@andrew.cmu.edu
www.cmu.edu/athletics (http://www.cmu.edu/athletics/)

Intercollegiate Athletics

Carnegie Mellon emphasizes excellence in its intercollegiate athletic programs, as well as in its classrooms. The university strongly believes that academic and athletic excellence can successfully coexist. Intercollegiate athletics are important in student life and make a positive impact on the educational experience. Experience as a student-athlete additionally provides benefits in professional and social endeavors following graduation.

Carnegie Mellon sports teams have competed intercollegiately since the early 1900s. In the past 16 years, the program has experienced extensive success. The Tartans have won 92 conference championships and competed in over 165 national championships since 1976. This success has been achieved while meeting all of the academic requirements of demanding programs and without athletic scholarships.

In 1986, Carnegie Mellon became a charter member of the University Athletic Association (UAA), an eight-team league of similar institutions with regard to academic and athletic programs. The UAA, a national association which geographically reaches as far north as Massachusetts, as far south as Atlanta and as far west as St. Louis and Chicago, sponsors intercollegiate competition in 23 sports including 10 for men and 10 for women. UAA members include Brandeis University, Case Western Reserve University, Carnegie Mellon University, Emory University, New York University, the University of Chicago, the University of Rochester and Washington University in St. Louis.

Carnegie Mellon, like the other seven UAA members, is a member of the National Collegiate Athletic Association (NCAA). Its intercollegiate teams compete on the Division III level, which prohibits athletic scholarships and operates under the true meaning of amateurism. Student-athletes who play at the varsity level are students first and athletes second. All students, both athletes and non-athletes, are treated equally with regard to admission and financial aid policies. Carnegie Mellon fully supports a policy of equity in resources and opportunities for women and men.

The university fields competitive teams in 19 sports. The Tartans compete in football, men’s and women’s golf, men’s and women’s soccer, men’s and women’s cross-country, men’s and women’s tennis, women’s volleyball, men’s and women’s basketball, men’s and women’s swimming and diving, men’s and women’s indoor and outdoor track and field, and softball.

Carnegie Mellon’s intercollegiate programs have consistently produced winners. The men’s golf team won the university’s first national championship in 2023 after placing sixth in 2022 and fourth in 2021. At the conclusion of the 2022 season, senior William Knauth was named the recipient of the Byron Nelson Award for his achievement in the classroom, on the course, and in the community, and a finalist for the Jack Nicklaus National Player of the Year Award.

The Tartans’ football team has won 19 conference championships, the latest coming in 2022, had a string of 35 consecutive winning seasons from 1975-2009, and has appeared in the NCAA Division III Championship playoffs seven times. The Tartans have also played in seven ECAC Bowl games. In 1979, Carnegie Mellon was awarded the Lambert Trophy as the best small college team in the northeast. In 2019, senior defensive lineman Michael Lohmeier became the fifth Tartan named as a finalist for the William V. Campbell Trophy, an award that recognizes an individual as the absolute best scholar-athlete in the nation amongst all divisions.

The men’s cross country team won its most recent conference championship in 2021 and has had a student-athlete or team compete at nationals for 21 straight seasons. In 2022, the women’s cross country team made its fifth straight appearance and eighth overall at the national meet. The 1998 team placed fourth nationally, the highest in program history.

The volleyball team has made five trips to the NCAA Tournament in the past six seasons and reached their highest AVCA national ranking in program history when they held the sixth spot for two weeks during the 2017 season.

The women’s soccer team has appeared in the NCAA tournament nine of the last 10 years. In 2019, the Tartans advanced to the NCAA Division III Women's Soccer Championship semifinals becoming the first women's team in Carnegie Mellon history to reach the semifinals of an NCAA tournament.

The men’s soccer team has competed in postseason play 16 times since 2000, including 14 trips to the NCAA tournament. Jon Hall was named CoSIDA Men's Soccer Academic All-America of the Year in back-to-back years (2008 and 2009).

In 2015-16, the women’s basketball team advanced to the Sweet 16 of the NCAA tournament for the first time in school history. The following season, 2016-17, senior Lisa Murphy was selected as the Jostens Trophy award winner. The award is a symbol of excellence for the Division III student-athlete; it is an honor given to the top women's basketball player for their excellence on the court, in the classroom and in the community. The 2021-22 team returned the program to postseason play and won the Eastern College Athletic Conference (ECAC) Championship for the second time in program history.

The men’s basketball team had played in seven postseason tournaments since 2004-05 with the 2022-23 team playing in the ECAC Championship tournament after tying for fourth place in the UAA.

Kayvon Fatahalian, a freshman computer science major on the men’s tennis team, won the NCAA National Singles Title in 2000 with a sophomore Abhishek Alla claiming the ITA National Small College Championship title in 2013. The women’s tennis team also produced an ITA National Small College Champion when sophomore Amy Staloch won the singles title in 2006. The women’s program has played in the NCAA Tournament in 16 of the last 17 years while the men’s program has played in nine NCAA Tournaments, the latest in 2021.

Both men’s and women’s swimming and diving and track and field teams annually qualify a number of athletes for the national championships. Swimming has produced a combined nine national champions with the men’s team finishing 11th in 2023 and the women 15th. The men’s track and field team finished fourth at the 2022 NCAA Indoor Track and Field Championships with three athletes earning runner-up finishes in their respective events. In 2023, senior Liz Barre won the women’s program’s first indoor NCAA individual championship with a victory in the pentathlon while the men’s program won the UAA Outdoor Championship for the fifth time.

In the spring of 2018, the women’s golf team, competing in its fourth year of varsity competition, finished fifth at the NCAA Division III Championships. Then in 2020, the sixth year of the women's golf program, the Tartans landed at the top position in the final Division III national rankings by Golfstat. The number one ranking was the first for a women's team sport at Carnegie Mellon. The 2022 and 2023 team’s placed fourth at the NCAA Championships.

The inaugural season of softball was in 2019. The team has produced four all-region honorees and set five team and four individual records in the 2023 season.

Carnegie Mellon has accumulated 192 Academic All-America honors given out by the College Sports Information Directors of America (CoSIDA) since 1973. There have been 147 that have earned the honor since the 2004-05 season. The Tartans have also produced 22 NCAA Postgraduate Scholars since 2007-08, which is a scholarship that is awarded to student-athletes who excel academically and athletically and who are in their final year of intercollegiate athletics competition.

In 2019, Carnegie Mellon Unveiled its Inaugural Athletics Hall of Fame. In October, 17 individuals and one historic team were inducted into the inaugural class.

To provide excellence throughout the athletic programs, the department employs full-time coaches in all varsity sports. Intercollegiate competition begins with the first football and soccer games in early September and ends with the NCAA track and field, golf, tennis and softball championships in late May. Students with athletic skills in any of the above mentioned sports are welcome to become members of the team. Participation is open to all students.

Recreation

In addition to providing for its more formal programs and teams, Carnegie Mellon’s athletic facilities are available for use by individual students on an extensive seven-day per week schedule.

The Cohon University Center has facilities for swimming, basketball, volleyball, squash, and racquetball, as well as cardio and strength equipment. Gesling Stadium provides outdoor soccer, football and track facilities. Tennis courts, located between the University Center and Margaret

Morrison, are lighted for night play. Outside basketball courts are located near Donner Hall. During the school year, they are open for use by students, faculty and staff.

These facilities are available to students, faculty and staff who have a valid Carnegie Mellon ID card. For hours, contact the Athletic Office at 412-268-5635, or visit our website (http://athletics.cmu.edu/landing/index/).

Physical Education

The Department of Physical Education provides an elective program with an emphasis on personal fitness and lifetime recreation, thus preparing students for physical activity after the college years. Most classes are offered on a mini-course system with each class running seven weeks in length.

This program of more than 60 courses is designed for all students, from the beginner to those students who have already developed some skill. Courses include weight training, personal fitness, racquetball, tennis, golf, weight training, swimming, badminton, indoor cycling and yoga. The department offers a wide variety of diversity in our course offerings. Instruction is also provided in several team sports. Carnegie Mellon also provides courses for American Red Cross certification in the four levels of swimming and lifeguard training.

Intramural Sports

For those who seek another level of competition or just like to participate and have fun, the Intramural Program provides recreation and relaxation for all students, faculty and staff, regardless of the degree of their natural athletic skills. The university prides itself on an intramural program which annually has over 3,000 participants. Men and women, both graduate and undergraduate, compete in more than 20 different activities. Major sports include flag football, soccer, volleyball, floor hockey. basketball, and softball. A few of our popular tournaments are ultimate frisbee, dodgeball, tennis, and badminton.

Through participation in this program, students are able to keep physically fit, put to good use various learned skills, and develop leadership, team play and sportsmanship. Intramural activities, like all sports endeavors, contribute to physical development, good health, and a sound state of mind, while providing keen competition and team spirit. In addition, intramural sports possess an inherent flexibility that allows for a limited commitment of time in light of academic priorities. The intramural program permits students from all departments to meet and socialize on an informal basis.

Fitness and Wellness

The university is well aware that fitness is a vital contributor to an individual's well-being and productivity. For this reason the department is committed to providing the entire campus community with the opportunity and resources to keep fit for the new century.

The Fitness and Wellness program provides educational services, programs, workshops and seminars. The Group X program provides over 70 exercise classes per week ranging from yoga and pilates to zumba and indoor cycling. These classes are free for all full time CMU students, faculty and staff. Personal training sessions are available for cost and provide an opportunity to work one on one with a certified strength coach in our athletic facilities.

Faculty

GARY ALDRICH, Associate Head Track & Field Coach/Instructor – M.S., Slippery Rock University,Carnegie Mellon, 2006–

MICHAEL BELMONTE, Assistant Men/Women Tennis – History, Duquesne; Carnegie Mellon, 2010–

BRANDON BOWMAN, Head Men's Soccer Coach – B.S., Centre College; Carnegie Mellon, 2017–

JOSH CENTOR, Assistant Director of Athletics – B.A., Brandeis University,Carnegie Mellon, 2008–

ALAN DEGENNARO, Strength and Conditioning CoachCarnegie Mellon, 2011–

SARA GAUNTNER, Assistant Director of Athletics for Instructional Programs & Recreation & Aquatics Director/Instructor – M.S., Duquesne University,Carnegie Mellon, 2005–

ANDREW GIRARD, Head Men's and Women's Tennis Coach/Instructor – B.S., Michigan Tech University,Carnegie Mellon, 2003–

ALICIA GORMAN, Diving Coach, Director of Acquatics – B.S., University of Tennessee; Carnegie Mellon, 2017–

ANDREW HELMS, Assistant Football Coach – B.S., Carnegie Mellon University; Carnegie Mellon, 2017–

JACQUIE HULLAH, Head Women's Basketball CoachCarnegie Mellon, 2011–

KIM KELLY, Head Women's Volleyball Coach/Instructor – MBA, Mt. St. Mary's University,Carnegie Mellon, 2005–

MATTHEW KINNEY, Head Swimming and Diving Coach/Instructor – M.S., Western Illinois,Carnegie Mellon, 2007–

RICHARD LACKNER, Head Football Coach/Instructor – B.A., Carnegie Mellon,Carnegie Mellon, 1979–

JEFF SIMMONS, Assistant Football Coach/Instructor – B.A., Geneva College; Carnegie Mellon, 2010–

PATTYE STRAGAR, Operations Manager for Fitness and Aquatics/Instructor – B.S., Northwestern University; Carnegie Mellon, 2003–

YON STRUBLE, Head Men's Soccer Coach/Instructor – M.S., Georgia State; Carnegie Mellon, 2010–

TONY WINGEN, Head Men's Basketball Coach/Associate Athletic Director/ Instructor – M.Ed., Springfield College; Carnegie Mellon, 1990–

Department of Athletics and Physical Education Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

69-005 Intro to Fly Fishing

Fall and Spring: 3 units
This introductory class explores the fundamentals of fly fishing. Aimed at the novice fly angler, topics include equipment selection, knot tying, basic entomology and fly selection, reading the water, and where to fly fish in Western Pennsylvania. Fly casting, the most important aspect of fly fishing, is taught.

69-101 Racquetball

Fall and Spring: 3 units
This course is designed to aid in developing the fundamental skills involved in racquetball. Techniques, rules and strategy are stressed. It is hoped that the student will develop a reasonable level of proficiency to enable participation on a leisure-time basis.

Course Website: http://www.cmu.edu/athletic/

69-102 Weight Training

Fall and Spring: 3 units
This course is designed to provide the opportunity for the inexperienced student to learn the effectiveness of a carefully planned weight-training program as a method of body development and the contributing benefit to performance in many sports.

69-103 Advanced Recovery & Restoration

Spring: 3 units
This course is designed to provide the opportunity for the physically active student to learn the effectiveness of a carefully planned recovery and restoration techniques as a method of body development and the contributing benefit to performance in many sports.

69-104 Practical Application of Sports Nutrition for Competitive Athletes

Spring: 3 units
This course will cover the following topics: macronutrient overview, specific overview of fats, carbohydrates, and protein, vitamin and minerals, nutritional needs for strength/power and endurance athletes, pre/during/post training nutritional needs for strength/power and endurance athletes, and other topics. FOR UNDERGRAD STUDENTS ONLY.

69-105 Agility & Circuit Training

Spring: 3 units
This course is designed to train the entire body combining fitness and core body work. We will do jumping and agility exercises to increase explosiveness and foot speed. Circuit training will be used to strengthen your core, arm, and leg muscles and will provide a cardiovascular workout.

69-106 Intro to Recreation

Fall: 3 units
This is a basic level class for first-year students only. This class is designed to teach students various fitness and recreational activities available to them on campus.

69-107 Walking for Fitness

Fall: 3 units
THIS COURSE IS IN PERSON ONLY FALL 2021. This course is an aerobic conditioning activity. A fast paced walk that is less wear and tear on your joints than what a running program will do.

69-110 Personal Fitness

Fall and Spring: 3 units
THIS COURSE IS IN PERSON ONLY FALL 2021. This course will be a conditioning course prescribed partially by the individual with assistance from the instructor to insure that the desired results will be achieved or at least pursued correctly. Individual goals will be the main concern. Stretching, aerobics, weight training and nutrition will be discussed.

69-112 Fitness Fusion

Fall and Spring: 3 units
A fun power-packed workout designed to introduce all aspects of fitness. This class combines simple exercises including cardio endurance with dynamic balance and stabilization. The class will fuse fitness while maximizing the benefits offered by training with concise, innovative, and effective exercises for the whole body. Every few weeks another aerobic activity will be added. We will start slowly so you can experience progressions and advance your training. During the fusion of strength, core, and flexibility, we will use a variety of "toys" to enhance your fun and fitness while fusing the total package of mind, body, and spirit.

69-113 Beginning Karate

Fall and Spring: 3 units
Beginning Karate teaches traditional Tang Soo Do (Korean Karate) by Master C. S. Kim and assistant instructors with specific standards and goals designed to help each student maximize potential as an individual, as well as a martial artist. Students will learn stretching and basic stances as well as blocking, punching, kicking, knee and elbow strikes, and open-handed techniques such as knife-hands. Proper etiquette will also be taught.

69-114 Intermediate Karate

Fall and Spring: 3 units
Intermediate Karate teaches a higher level of the traditional martial arts with specific standards and goals designed to help each student maximize potential as an individual, as well as a martial artist. Through traditional Tang Soo Do (Korean Karate) taught by Master C. S. Kim and assistant instructors, you will find many opportunities to gain specific knowledge which will apply not only in your martial arts training, but also in the improvement of your daily quality of life.

69-120 Topics in Health and Physical Activity

Fall and Spring: 3 units
This course is a weekend seminar covering a variety of topics. Dates of the course will be TBD once instructor sets dates. This course is designed to expose students to a comprehensive overview of what it means to be healthy, including: stress management strategies, healthy eating habits, importance of sleep, and the benefits of various exercise methods. The course will be presented using both a traditional lecture style, and hands-on practice. A few outside speakers will be brought in to speak in their area of expertise. Students should come prepared to exercise.

69-129 Rape Agression Defense Systems (RAD)

Fall and Spring: 3 units
Self Defense for Women - is a course specifically designed to increase women's awareness of potential sexual assault and to provide physical techniques to respond to such an act. It is intended for women only because it is believed that the presence of males in class (other than instructors or other authorized persons) can alter the emotional and physical responses of women to class material and thereby hinder their ability to reach course objectives. It is of the utmost importance that women be able to maximize their opportunity to learn in the company of like-minded students. The core of the course is based upon the principles of the Rape Aggression Defense System (R.A.D.)which was conceived and developed by Larry N. Nadeau. His goal in developing R.A.D. is also its motto: "To develop and enhance the options of self-defense, so they may become viable considerations to the woman who is attacked." This course is composed of three sections: risk reduction principles, physical defense techniques, and simulation. Risk reduction principles include a thorough review of personal self-awareness and amp; the environment, whether in the home, neighborhood, or unfamiliar community. Physical defense techniques include the introduction to bodily strikes with hands, kicks with the feet, and defenses against grabs and amp; holds. Simulation is the activity that attempts to incorporate, via physical demonstration, all emotional and amp; physical techniques that have been taught through the acting out of scenarios involving instructors (padded/protected) as attackers, and students (padded/protected) responding to the assault.

69-130 Beginning Tennis

Fall and Spring: 3 units
This course is designed to familiarize the student with the rules of tennis and to develop the skills needed to become proficient for recreational play. During the first half of the course, all tennis strokes will be covered and reviewed in detail. The second half of the course will focus mostly on competitive games and match-play.

69-131 Volleyball

Spring: 3 units
This course is designed to familiarize the student with the rules of volleyball and to develop the skills needed to become proficient for recreational play.

69-132 Advanced Tennis

Fall: 3 units
This course will consist mainly of tennis drills and discussions related to singles, doubles, and match strategy. In addition to being able to successfully execute all tennis strokes, students should also already have significant tennis match experience.

69-134 Beginning Golf

Fall and Spring: 3 units
This course is designed to give the student all the skills necessary to play a satisfactory game of golf. The long game, the short game and putting are covered. It is a leisure time sport that is challenging and can be used by the student for the rest of his/her life.

69-135 Soccer Skills

Spring: 3 units
This course is designed to familiarize the student with the rules of soccer and to develop the skills needed to become proficient for recreational play.

69-136 Basketball Skills

Fall and Spring: 3 units
This course is designed to familiarize the student with the rules of basketball and to develop the skills needed to become proficient for recreational play.

69-137 Ultimate Frisbee

Fall: 3 units
This class is designed to teach basic Frisbee skills. This class is a great conditioning/cardio class with high energy. It is a fun team game to play.

69-139 Indoor Soccer Skills

Spring: 3 units
This course is designed to familiarize the student with the rules of soccer and to develop the skills needed to become proficient for recreational play.

69-140 Squash

Fall and Spring: 3 units
This course is designed to aid in developing the fundamental skills involved in squash. Techniques, rules and strategy are stressed.

69-141 Beginning Soccer

Spring: 3 units
This class is designed for beginner soccer players. This class will teach you soccer skills and techniques to become a better player.

69-142 Beginning Fencing

Spring: 6 units
This course will cover the basic skills needed for fencing with the foil. Footwork, attacks, and defenses will be practiced. Competition rules and strategies will be discussed. Students will fence each other and the instructor in almost every class.

69-143 Dodgeball

Spring: 3 units
This class is designed to teach the rules of dodgeball. The students will learn the national rules and play against classmates.

69-144 Diamond Sports

Spring: 3 units
This course is designed to familiarize the student with the rules of softball and wiffleball and to develop the skills needed to become proficient for recreational play. Students will play each other or the instructor in almost every class.

69-145 Beginning Softball

Fall and Spring: 3 units
Students will learn beginning softball skills-throwing, hitting, running

69-146 Team Handball

Fall: 3 units
Team Handball or European Handball - This is an introductory level class that will cover the basics of the sport including the rules, organization, and basic game play. Students will be expected to learn the rules and participate in play on a daily basis.

69-150 Beginning Swimming

Fall: 3 units
This basic course is designed to equip the non-swimmer with fundamental skills and knowledge to assure reasonable safety in, on or about the water. Areas covered include the basic swimming strokes, basic diving, safe and efficient entry into the water, and some elementary forms of rescue.

69-151 Introduction to Yoga

Fall and Spring: 3 units
THIS COURSE IS IN PERSON ONLY FALL 2021. This course is designed for the beginning yoga student who wants to gain a solid foundation of yoga poses and the benefits a yoga practice has to offer. The course is also for those who have experience in Yoga and want to practice and improve their basic skills.

69-153 Lifeguard Training

Spring: 3 units
This class is the American Red Cross Lifeguard Training course. Students who complete certification will be eligible to be employed as lifeguards. Attendance is required. There will be a fee from the American Red Cross- the instructor will share this with you upon completion of the course requirements.

69-155 Cardio Fitness/Sculpt

Fall and Spring: 3 units
A total body fitness class for men and women that incorporates stretching for flexibility, exercises for strength and movement to increase cardiovascular improvement.

69-156 First Aid/CPR

Spring: 3 units
A basic course in treatment and care of injuries in emergency situations. Topics will include legal liability, prevention of injuries, nutrition and cardiovascular conditioning. The course will conclude with theoretical and practical application of cardiopulmonary resuscitation. Upon completion of the course students will receive Red Cross Certification. There will be a fee for this class of $15.00. This fee will be deducted from the student's account.

69-157 Swimming Stroke Improvement

Fall: 3 units
This course is designed to provide the student with the opportunity to learn the elements of good swimming. A wide range of strokes, basic diving, safety, endurance, and versatility in the water will be covered for all students. Experienced swimmers will have the opportunity to perfect their strokes.

69-160 Swim-Fit

Fall and Spring: 3 units
Must be able to complete a 1000 yard swim (40 laps) prior to entering the class ; this is not a learn-to-swim class. Pre and post timed swims, deep water treading, lap swimming interval training. Average workout is around 2000 yards.

69-165 Cycling Core

Fall and Spring: 3 units
Indoor cycling classes are riding on a stationary bike while getting a great workout, experiencing several styles of training, and listening to music. All are welcome and #8212;beginner to advanced and #8212;you set the workout pace to various intensities. This course is for those participants who want to gain knowledge and experience of riding for endurance, speed work, race training, strength training, and/or visionary riding. Each class will be formatted to take the rider to their levels of advancement and #8212;beginner to advanced and #8212;all doing the same workout. Bikes are provided. No prior bike experience is necessary. No special footwear required and #8212;bike shoes are welcome and #8212;and tennis shoes at least are a must. Come along for the ride of a lifetime while having fun and getting into shape.

69-167 Beginning Ballroom Dance

Spring: 2 units
This class provides an overview of six American Style Ballroom Dances: Foxtrot, Waltz, Tango, Cha Cha, Rumba, Swing. Participants will learn three or four basic step patterns in each dance, the timing of each pattern, leading and following principles and the unique characteristics of each dance. At the end of this course, participants will be able to dance comfortably at a social dance. It is recommended that suede bottomed dance shoes be worn, but not required.

69-175 African-Brazil Dance

Fall: 2 units
This class incorporates African-Modern dance technique (specifically elements of Dunham and Horton technique) and applies it to dance movements from West Africa, Haiti, and /or Brazil. Students will build strength, alignment, and stamina while experiencing the joy of dancing to the exciting and mesmerizing music of these regions. Open to non-drama and drama majors.

69-176 Non-Majors Jazz

Spring: 3 units
This class is designed for those students who would like to continue their study in jazz but are not enrolled in the CFA department. They will learn the basics and progression movements in the area of jazz dancing. This is for all levels of participants.

69-195 Emergency Medical Technician 1

Fall and Spring: 12 units
The Emergency Medical Technician provides students with a basic knowledge of Emergency Medicine, and enables students to take the National Registry EMT Certification exam and become certified at the state and national level. This course is cross-enrolled through the Community College of Allegheny County (CCAC) and will require registration with CCAC on the first day of class. This will require a fee, which has yet to be determined. Due to state laws and classroom hours requirements, all lectures are mandatory with very few exceptions. This class will meet on around 2 Saturdays, which will be announced on the first day of class. This class is also offered in two parts. The first part (69-195) is offered during mini-2 and the second part (69-195) is offered during the full spring semester. You must attend both parts in order to be eligible to take the National Registry EMT Certification exam. Please email info@cmuems.org with any questions you might have.

Reserve Officers' Training Corps (ROTC)

Department of Aerospace Studies (Air Force ROTC)

Lt Col James Straub, *Detachment 730 Commander*
Location: University of Pittsburgh, 4200 Fifth Avenue, 2917 Cathedral of Learning
Phone: 412-624-6031
afdet730@pitt.edu
www.afrotc.pitt.edu (http://www.afrotc.pitt.edu)

The local AFROTC program is administered by the Department of Aerospace Science at the University of Pittsburgh. This program is available to undergraduate students at fourteen “cross-town” universities via enrollment through agreement with the University of Pittsburgh. Students must have at least six semesters (three full academic years) of school remaining to successfully complete AFROTC graduation requirements. Upon successful completion of university academic and ROTC requirements, students will earn a commission as a Second Lieutenant in the US Air Force.

Students will complete one or two years in the General Military Course (GMC) before competing for an enrollment allocation into a four-week summer leadership training program. After completion of the summer training program, students are enlisted into the Professional Officer Course (POC), where they will take on role leading anywhere from 10–50 of their fellow cadets in weekly activities. *Students are under NO contractual obligation to the Air Force until entering the POC or accepting an Air Force scholarship.* In addition to the academic portion of the curriculum, each student attends a weekly two-hour, hands-on “laboratory” that tests both their followership and leadership abilities amongst their peers. This lab is used to practice various leadership and management techniques and groom students into future military leaders. Three and three-and-a-half year scholarships are available to qualified students in certain areas of study. Most AFROTC scholarships cover tuition plus lab fees, books, plus each scholarship awardee receives a tax free monthly stipend that ranges between $300–500 per month.

Department of Military Science (Army ROTC)

William Perez, *Army ROTC, Three Rivers Battalion Scholarship and Enrollment Officer*
Location: University of Pittsburgh, 315 South Bellefield Avenue, Room 306
Phone: 412-624-6254
Fax: 412-624-7793
WRP14@pitt.edu

The Army Reserve Officers’ Training Corps (ROTC) program supporting Carnegie Mellon University is located at the University of Pitts-burgh. It exists to train the future officer leadership of the United States Army and offers opportunities and challenges that can put college students on the fast track to success in life. ROTC provides a combination of academics and important hands-on training, in addition to physical and mental challenges that will help students succeed in college and beyond. Through the training in ROTC, students will develop the confidence, self-esteem, motivation and leadership skills they will need regardless of their career plans.

The Four-Year Program

The traditional Four-Year program is divided into two parts. The Basic Course is taken in the freshman and sophomore years. There is no commitment for non-scholarship students at this level. Upon successful completion of the Basic Course, students are eligible for the Advanced Course, taken in the junior and senior years. At the beginning of the Advanced Course, students will decide whether or not they wish to become officers in the Army and enter into a formal contract. During the summer between the junior and senior years, students are required to attend the the Leader Development and Assessment Course (LDAC). Upon successful completion of a University degree and the Army ROTC program, students are commissioned into the United States Army as a Second Lieutenant.

The Two-Year Program

If the first two years of ROTC are not taken, students can attend the Leader’s Training Course (LTC) during the summer between the sophomore and junior year. This camp will qualify students to begin the Advanced Course in their junior year or in the first year of a two-year graduate program. Or, if students have served in the active duty military, attended a military academy for one year, participated in JROTC for three years or belong to a Army National Guard or Army Reserve unit, they already qualify for entrance into the Advanced Course.

The Alternative Entry Program

The Alternative Entry Program is designed for academic junior students with no prior qualifying military training but are otherwise qualified. This option allows students to contract into the Advanced Course without receiving placement credit for the basic course. Students accepted into this program must complete the Leader’s Training Course and the Leader Development and Assessment Course during the summer months.

Curriculum

Freshman Year		Units
30-101	Introduction to Military Leadership - Fall	5
30-102	Foundations of Leadership- Spring	5

Sophomore Year		Units
30-201	Leadership Dynamics and Application- Fall	5
30-202	Applications in Leadership and Combat Power- Spring	5

Junior Year		Units
30-301	Basic Leader Planning and Combat Operations- Fall	5
30-302	Advanced Leader Planning and Combat Operations- Spring	5
Leadership Development & Assessment Course (six-week required summer camp)		

Senior Year		Units
30-401	Progressive Leadership Theory and Applications- Fall	5
30-402	Transition to the Profession of Arms- Spring	5

Army ROTC Scholarships

Army ROTC offers four, three and two year full scholarships with additional annual allowances of $900 for books and a monthly stipend. High school, undergraduate and incoming two-year graduate students are eligible to apply. For application and information call ROTC at the University of Pittsburgh at (412) 624-6254/6197.

The Simultaneous Membership Program (SMP)

This program allows students to become members of the Army National Guard or the Army Reserves while enrolled in Army ROTC. Students in the Advanced Course who are SMP are paid for their Guard/Reserve training. The benefit of this program is that students in the Advanced Course are able to act as Army officers in their National Guard or Reserve unit, receiving valuable leadership experience.

Summer Programs

Leadership Development & Assessment Course
This 35-day camp is a requirement for all contracted students. Students attend the summer between their junior and senior year. Students are placed in various leadership positions throughout Camp and their skills and abilities will be tested and evaluated in preparation of a commission in the United States Army. All expenses are paid by the Army. Students are paid while attending.

Leader’s Training Course
This 35-day camp is taken as a prerequisite for entry into the Advanced Course if the Basic Course cannot be fulfilled. It is taken the summer before

the junior year. All expenses are paid by the Army. Students are paid while attending.

Army Adventure Training
ROTC students may participate in Airborne School, Air Assault School, Northern Warfare School and Mountain Warfare School the summer before the sophomore and junior year. These courses range from two to four weeks and students must arrive in top physical condition. All expenses are paid by the Army.

Extracurricular Activities

Rangers: Army ROTC students are eligible to participate in the Cadet Ranger Club. The Club conducts physically and mentally challenging extracurricular training to promote fitness, teamwork, self-confidence and fellowship. Training includes physical fitness, rappelling, rope bridging, tactics, hiking, climbing, weapons training and orienteering.
Scabbard & Blade: National Honor Society consisting of cadets/midshipmen from Army, Air Force and Naval ROTC.
Rho Tau Chi: Military fraternity established for the members of the various branches of ROTC. Purpose is to draw together cadets to increase communication and feelings of goodwill between the Cadet Corps and the community. Cadets participate in a variety of community service projects.
Color Guard: Dedicated group of Army ROTC cadets who train and perform to present the American flag and Army colors at football and basketball games and various community events.

Department of Naval Science (Naval ROTC)

Mike Danko, *ROTC and Veterans Affairs Coordinator*
Captain Michael Tomon, U.S.N., *Commanding Officer*
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Fax: 412-268-6381
www.cmu.edu/nrotc (https://www.cmu.edu/nrotc/)

The Department of Naval Science was established 16 December 1987. Its mission is to prepare young men and women mentally, morally, and physically, and to instill in them the highest qualities of duty, honor, and loyalty, in preparation for leadership positions in the naval service.

Carnegie Mellon’s Naval Reserve Officers Training Corps (NROTC) is designed for young men and women who are seeking a challenging academic experience and who desire to serve their country as officers in the Navy or Marine Corps after graduation.

NROTC midshipmen lead the same campus life as other Carnegie Mellon students. They make their own arrangements for room and board, choose a preferred area of study and participate in extracurricular activities. Midshipmen wear civilian clothes to classes but wear uniforms one day of the week. NROTC students are active in all facets of university life; many are in positions of leadership in student government, on varsity and intramural sports teams, in campus clubs, and other student organizations. The NROTC program seeks students who are bright, ambitious, enthusiastic leaders whose lives are enriched by their education at Carnegie Mellon and by their involvement in NROTC.

Four-Year Scholarship Program

The four-year scholarship program provides full tuition and university fees, $750 for textbooks per year, uniforms, and a $250 per month tax-free subsistence allowance to students during their freshman year. This stipend then increases to $300 during their sophomore year, $350 for their junior year and $400 for their senior year. Midshipmen must complete the university-approved curriculum of their choice, including courses in calculus and calculus-based physics (Navy Option Only), and specified courses in naval science subjects. Paid summer training periods are also provided. Scholarships are awarded on the basis of a nationwide competition before the start of the freshman year. Midshipmen commissioned through the scholarship programs become officers in the Navy or Marine Corps and incur a four-year active duty obligation in a selected area of the naval service.

College (Non-Scholarship) Programs in NROTC
Qualified students may participate in NROTC as college program (non-scholarship) midshipmen and earn commissions in the Navy or Marine Corps Reserve upon graduation. The active duty obligation for this program is three years. Students receive all naval science textbooks and uniforms. Additionally, if awarded advanced standing during their junior and senior years, they receive a tax-free subsistence monthly allowance of $350 and $400 respectively. A paid summer training period is provided between the junior and senior year. College program students may compete for three- and two-year scholarships described in the following paragraph.

College Program Three- and Two-Year Scholarships
Three-year scholarships are available on a competitive basis to those qualifying college program (non-scholarship) NROTC students who have demonstrated leadership and academic excellence during their freshman or sophomore year and are nominated for the scholarship by the Professor of Naval Science. Scholarship benefits are identical to those provided by the four-year scholarship program. Active duty obligation is four years upon commissioning in a selected area of the naval service.

Two-Year National Scholarship Program
Sophomores who have not participated in the NROTC program may apply for a nationally competitive two-year NROTC scholarship. The two-year scholarship program provides the same benefits as the four-year program for a period of 20 months. Students must apply for this program no later than February of their sophomore year. Students selected for this program attend the Naval Science Institute during the summer before their junior year to complete required naval science course material.   A paid summer training period is provided between the junior and senior years. Commissionees incur a four-year active duty obligation upon graduation in a selected area of the naval service.

Curriculum

The sequence of naval science courses is the same for all officer candidates for the first three semesters. Midshipmen accepted into the Marine Corps option program will have curriculum variations starting with their third year. Additionally, some candidates may be required to complete courses in American military affairs, national security policy, English, mathematics, and/or the physical sciences. Descriptions of the course requirements for each candidate classification (scholarship/college program) may be obtained from the Department of Naval Science office.

All scholarship and college program students are required to attend a weekly 1.5 hour Naval Laboratory (32-100) where professional orientation, military drill, physical fitness, and leadership are emphasized. Guest speakers from the Fleet are frequent participants in these laboratories. Naval Science courses are open to all students. Since these are required courses for NROTC students, they will be given priority in enrollment. Remaining spaces will be filled through the normal university registration process.

Naval Professional Academic Courses

Freshman Year		Units
32-100	Naval Laboratory	3
32-101	Introduction to Naval Science	6
32-102	Seapower and Maritime Affairs	6

Sophomore Year		Units
32-200	Naval Laboratory	3
32-201	Leadership & Management	9
32-212	Navigation *	9

Junior Year		Units
32-300	Naval Laboratory	3
32-310	Evolution Of Warfare **	9
32-311	Naval Ship Systems I-Engineering *	9
32-312	Naval Ship Systems II-Weapons *	9

Senior Year		
32-400	Naval Laboratory	3
32-402	Leadership and Ethics	9
32-410	Amphibious Warfare/Operations & The Fundamentals of Maneuver Warfare **	9
32-411	Naval Operations and Seamanship *	9

Footnotes:
* Required of students in the Navy Option
** Required of students in the Marine Option
All other courses are required of all students in the program.

Naval ROTC Faculty

JEFF CORAN, Captain, USN – M.S., Rensselaer Polytechnic Institute; Carnegie Mellon, 2014–

ROTC Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

Aerospace Studies-ROTC Courses

31-101 Foundations of the United States Air Force

Fall: 3 units
AS100 is a survey course designed to introduce cadets to the United States Air Force and Air Force Reserve Officer Training Corps. Featured topics include: mission and organization of the Air Force, officership and professionalism, military customs and courtesies, Air Force officer opportunities, and an introduction to communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

31-102 Foundations of the United States Air Force

Spring: 3 units
AS100 is a survey course designed to introduce cadets to the United States Air Force and Air Force Reserve Officer Training Corps. Featured topics include: mission and organization of the Air Force, officership and professionalism, military customs and courtesies, Air Force officer opportunities, and an introduction to communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

31-105 Air Force Leadership Laboratory

All Semesters
The AS100 and AS200 Leadership Laboratory courses (LLABs) include a study of Air Force customs and courtesies, drill and ceremonies, and military commands. The LLAB also includes studying the environment of an Air Force officer and learning about areas of opportunity available to commissioned officers. The AS300 and AS400 LLABs consist of activities classified as leadership and management experiences. They involve the planning and controlling of military activities of the cadet corps, and the preparation and presentation of briefings and other oral and written communications. LLABs also include interviews, guidance, and information, which will increase the understanding, motivation, and performance of other cadets.

31-106 Air Force Leadership Laboratory

All Semesters
The AS100 and AS200 Leadership Laboratory courses (LLABs) include a study of Air Force customs and courtesies, drill and ceremonies, and military commands. The LLAB also includes studying the environment of an Air Force officer and learning about areas of opportunity available to commissioned officers. The AS300 and AS400 LLABs consist of activities classified as leadership and management experiences. They involve the planning and controlling of military activities of the cadet corps, and the preparation and presentation of briefings and other oral and written communications. LLABs also include interviews, guidance, and information, which will increase the understanding, motivation, and performance of other cadets.

31-107 Air Force Leadership Laboratory

All Semesters
The AS100 and AS200 Leadership Laboratory courses (LLABs) include a study of Air Force customs and courtesies, drill and ceremonies, and military commands. The LLAB also includes studying the environment of an Air Force officer and learning about areas of opportunity available to commissioned officers. The AS300 and AS400 LLABs consist of activities classified as leadership and management experiences. They involve the planning and controlling of military activities of the cadet corps, and the preparation and presentation of briefings and other oral and written communications. LLABs also include interviews, guidance, and information, which will increase the understanding, motivation, and performance of other cadets.

31-108 Air Force Leadership Laboratory

All Semesters
The AS100 and AS200 Leadership Laboratory courses (LLABs) include a study of Air Force customs and courtesies, drill and ceremonies, and military commands. The LLAB also includes studying the environment of an Air Force officer and learning about areas of opportunity available to commissioned officers. The AS300 and AS400 LLABs consist of activities classified as leadership and management experiences. They involve the planning and controlling of military activities of the cadet corps, and the preparation and presentation of briefings and other oral and written communications. LLABs also include interviews, guidance, and information, which will increase the understanding, motivation, and performance of other cadets.

31-201 The Evolution of Air and Space Power

Fall: 3 units
The AS200 course designed to examine general aspects of air and space power through a historical perspective. Utilizing this perspective, the course covers a time period from the first balloons and dirigibles to the space-age global positioning systems of the Persian Gulf War. Historical examples are provided to extrapolate the development of Air Force capabilities (competencies), and missions (functions) to demonstrate the evolution of what has become today's USAF air and space power. Furthermore, the course examines several fundamental truths associated with war in the third dimension: e.g. Principles of War and Tenets of Air and Space Power. As a whole, this course provides the cadets with a knowledge level understanding for the general element and employment of air and space power, from an institutional doctrinal and historical perspective. In addition, the students will continue to discuss the importance of the Air Force Core Values with the use of operational examples and historical Air Force leaders and will continue to develop their communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

31-202 The Evolution of Air and Space Power

Spring: 3 units
The AS200 course designed to examine general aspects of air and space power through a historical perspective. Utilizing this perspective, the course covers a time period from the first balloons and dirigibles to the space-age global positioning systems of the Persian Gulf War. Historical examples are provided to extrapolate the development of Air Force capabilities (competencies), and missions (functions) to demonstrate the evolution of what has become today's USAF air and space power. Furthermore, the course examines several fundamental truths associated with war in the third dimension: e.g. Principles of War and Tenets of Air and Space Power. As a whole, this course provides the cadets with a knowledge level understanding for the general element and employment of air and space power, from an institutional doctrinal and historical perspective. In addition, the students will continue to discuss the importance of the Air Force Core Values with the use of operational examples and historical Air Force leaders and will continue to develop their communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

31-301 Air Force Leadership Studies

Fall: 9 units
AS300 is a study of leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer. Case studies are used to examine Air Force leadership and management situations as a means of demonstrating and exercising practical application of the concepts being studied. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences in officer-type activities, giving students the opportunity to apply the leadership and management principles of this course.

31-302 Air Force Leadership Studies

Spring: 9 units
AS300 is a study of leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer. Case studies are used to examine Air Force leadership and management situations as a means of demonstrating and exercising practical application of the concepts being studied. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences in officer-type activities, giving students the opportunity to apply the leadership and management principles of this course.

31-401 National Security Affairs and Preparation for Active Duty

Fall: 9 units
AS400 examines the national security process, regional studies, advanced leadership ethics, and Air Force doctrine. Special topics of interest focus on the military as a profession, officership, military justice, civilian control of the military, preparation for active duty, and current issues affecting military professionalism. Within this structure, continued emphasis is given to refining communication skills. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences, giving students the opportunity to apply the leadership and management principles of this course.

31-402 National Security Affairs and Preparation for Active Duty

Spring: 9 units
AS400 examines the national security process, regional studies, advanced leadership ethics, and Air Force doctrine. Special topics of interest focus on the military as a profession, officership, military justice, civilian control of the military, preparation for active duty, and current issues affecting military professionalism. Within this structure, continued emphasis is given to refining communication skills. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences, giving students the opportunity to apply the leadership and management principles of this course.

Military Science-ROTC Courses

30-101 Introduction to Military Leadership

Fall: 5 units
In this course, students will be introduced to the fundamentals of Army leadership, management and basic military skills. The course emphasizes the Army's "Principles of Leadership" and familiarizes the student with rifle marksmanship, orienteering and map reading, rappelling, basic lifesaving skills and the wear of the Army uniform. In addition, students will enhance their time management, decision-making and physical fitness abilities. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided.

30-102 Foundations of Leadership

Spring: 5 units
This course is a continuation of the subjects and skills taught in 30101. In addition to extending the student's abilities in the areas of leadership, orienteering and map reading, lifesaving and other basic military concepts, the course also introduces the student to the employment of military units. Individual topics covered include the Army's emerging technological enhancements, the Army organization and structure and the wartime policies and principles. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided.

30-201 Leadership Dynamics and Application

Fall: 5 units
In this course, students will delve more deply ino the Army's leadership and management techniques, including the application of those techniques in faculty-supervised practical exercises. The course also seeks to enhance the student's abilities in orienteering and map reading, terrain analysis, advanced lifesaving techniques and physical fitness. Students are introduced to the values that define the United States Army as an American institution, and each student continues to enhance his or her physical development under the supervision of the faculty. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided.

30-202 Applications in Leadership and Combat Power

Spring: 5 units
This course continues the study of the topics covered in 30201 and focuses upon practical application of the leadership and management techniques learned in the fall semester. The student develops and applies advanced map reading, terrain analysis, problem-solving and decision-making skills in practical exercises. Additionally, the student is introduced to the Army's formal orders process, used to maneuver and sustain Army forces on the modern battlefield. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided.

30-301 Basic Leader Planning and Combat Operations

Fall: 5 units
This course offers an in-depth analysis and focused practical application of leadership and management techniques. The emphasis in the course is on leader development and the goal is to enhance the student's ability to perform effectively in a stressful decision-making environment. As such, time management, decision-making, advanced military skills, troop-leading procedures and advanced physical training are emphasized. The course requires participation in a demanding physical training program to prepare contracted students for the Army's R.O.T.C. Leader Development and Assessment Course (LDAC). Each student must participate in field training exercises and is expected to wear the Army uniform, which will be provided. Prerequisites: Class is open only to contracted students. Veterans with two or more years of service may enroll with approval.

30-302 Advanced Leader Planning and Combat Operations

Spring: 5 units
This course builds upon the foundation laid in the fall semester with the objective of fully preparing contracted students for participation in the Army's challenging R.O.T.C. Leader Development and Assessment Course (LDAC). The course extends and enhances the student's leadership, management, communication, fitness and basic military skills in preparing the student for commissioning as an officer in the United States Army. Practical exercises are used to reinforce all of the skills that the student has developed over the course of the military science instruction. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided. Prerequisites: Class is open only to contracted students. Veterans with two or more years of service may enroll with approval.

30-401 Progressive Leadership Theory and Applications

Fall: 5 units
This course is the first of two semester courses that serve as a capstone designed to transition the student from cadet to U.S. Army officer. Students are assigned to command and staff positions within the cadet battalion, corresponding to those found in United States Army units. Students perform the duties of the staff or command as assigned and interact with the other cadets as part of a functioning command organization. In addition to studying the operations and organizations of the U.S. Army, students are required to plan and execute the required training and activities in leading the underclasss cadets. A variety of topics of current interest are covered. Guest speakers are commonly invited to discuss their military experiences or their perspectives on military-related topics. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided. Prerequisites: Class is open only to contracted students.

30-402 Transition to the Profession of Arms

Spring: 5 units
This capstone course completes the transition from cadet to Army officer and concludes with the student's commissioning into the United States Army. During the semester, students continue to act in accordance with their assigned staff and command responsibilities and they prepare for their duties as a Lieutenant in the Army. This course covers personal and performance counseling, evaluation of subordinate leaders and team-building skills as well as military justice and discipline. Students bring to bear all of the skills and knowledge that they have accrued over the prior semesters in the Department of Military Science. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided. Prerequisites: Class is open only to contracted students.

Naval Science - ROTC Courses

32-100 Naval Laboratory

Fall and Spring: 3 units
Military drill, physical fitness, and leadership seminars.

32-101 Introduction to Naval Science

Fall: 6 units
A general introduction to the naval profession and to concepts of Seapower. Instruction emphasizes the mission, organization, and warfare components of the Navy and Marine Corps. Included is an overview of officer and enlisted ranks and rates, training and education, and career patterns. The course also covers naval courtesy and customs, military justice, leadership, and nomenclature. This course exposes the student to the professional competencies required to become a naval officer.

32-102 Seapower and Maritime Affairs

Spring: 6 units
This course surveys US naval history from its European origins to the present with emphasis on major developments and the geopolitical forces shaping these developments. Also included is discussion of the theories and writings of naval historian and strategist Alfred Thayer Mahan. The course will finish by covering present day concerns in seapower and maritime affairs including the economic and political issues of merchant marine commerce, the law of the sea, the navy and merchant marine of the former Soviet Union (FSU), and a comparison of US and FSU maritime strategies to include the rise and decline of the Soviet Navy.

32-200 Naval Laboratory

Fall and Spring: 3 units
Military drill, physical fitness, and leadership seminars.

32-201 Leadership & Management

Fall: 9 units
This course is a comprehensive advanced-level study of organizational behavior and management. Topics include a survey of the management functions of planning, organizing, and controlling; an introduction to individual and group behavior in organizations; an extensive study of motivation and leadership. Major behavioral theories are explored in detail. Practical applications are explored by the use of experiential exercises, case studies, and laboratory discussions. Other topics developed include decision-making, communication, responsibility, authority and accountability.

32-212 Navigation

Spring: 9 units
An in-depth study of piloting and an introduction to celestial navigation theory. Students learn piloting skills including the use of charts, visual and electronic aids, and the theory and operation of magnetic and gyro compasses. Students develop practical skills in both piloting and celestial navigation. Other topics include tides, currents effects of wind and weather, plotting, use of navigation instruments, types and characteristics of electronic navigation systems, and the typical day's work in navigation. Also included is a study of the international and inland rules of the nautical road, relative motion, vector analysis theory, and relative motion problems.

32-300 Naval Laboratory

Fall and Spring: 3 units
Military drill, physical fitness, and leadership seminars.

32-310 Evolution Of Warfare

Fall: 9 units
This course is to provide the student with a very basic understanding of the art and concepts of warfare from the beginning of recorded history to the present day. The intent of the curriculum is to familiarize the student with an understanding of the threads of continuity and the interrelations of political, strategic, operational, tactical, and technical levels of war from the past, while bringing into focus the application of these same principles and concepts to the battlefields of today and the future.

32-311 Naval Ship Systems I-Engineering

Fall: 9 units
A detailed study of ship characteristics and types including ship design, hydrodynamic forces, stability, compartmentalization, propulsion, electrical and auxiliary systems, interior communications, ship control, and damage control. Included are basic concepts of the theory and design of steam, gas turbine, internal combustion, and nuclear propulsion. Shipboard safety and firefighting are also discussed.

32-312 Naval Ship Systems II-Weapons

Spring: 9 units
This course outlines the theory and employment of weapons systems. The student explores the processes of detection, evaluation, threat analysis, weapon selection, delivery, guidance and explosives. Fire control systems and major weapon types are discussed, including capabilities and limitations. The physical aspects of radar and underwater sound are described in detail. The facets of command, control, and communications are explored as a means of weapons system integration.

32-400 Naval Laboratory

Fall and Spring: 3 units
Military drill, physical fitness, and leadership seminars.

32-402 Leadership and Ethics

Spring: 9 units
The study of naval junior officer responsibilities. The course exposes the student to a study of ethics, decision making and responsibility as well as counseling methods, military justice administration, naval human resources management, directives and correspondence, naval personnel administration, material management and maintenance and supply systems. This capstone course in the NROTC curriculum builds on and integrates the professional competencies developed in prior course work and professional training.

32-410 Amphibious Warfare/Operations & The Fundamentals of Maneuver Warfare

Fall: 9 units
A historical survey of the development of amphibious doctrine and the conduct of amphibious operations. Emphasis is placed on the evolution of amphibious warfare in the twentieth century, especially during World War II. Focus is applied to four main themes: political/strategic situation, sea-to-land transitions, tactics ashore, and development of amphibious technology. Present day potential and limitations on amphibious operations, including the rapid deployment force concept, are explored.

32-411 Naval Operations and Seamanship

Fall: 9 units
Designed as an introduction to naval operations and shipboard evolutions, vessel behavior and characteristics in maneuvering, applied aspects of ship handling, and afloat communications. This course builds upon the information presented in Navigation 32-212, Engineering 32-311, and Weapons Systems 32-312. An understanding of the nautical rules of the road, relative motion and vector analysis are utilized in discussion regarding the conduct of naval operation to include formation tactics and ship employment. The student will also be introduced to the various components of naval warfare and their role in sea control and power projection missions within naval and joint operations.

Degrees Offered

With cutting-edge brain science, path-breaking performances, innovative start-ups, driverless cars, big data, big ambitions, Nobel and Turing prizes, hands-on learning, and a whole lot of robots, CMU doesn't imagine the future, we create it. Carnegie Mellon offers a wide range of programs in seven schools and colleges, and has consistently ranked high in a number of disciplines (https://www.cmu.edu/about/).

To browse the primary degrees offered , select a school or college below. For a list of minors, please see Undergraduate Options (p. 22).

College of Engineering

Interdepartmental

- M.S. in Energy Science, Technology and Policy
- M.S. in Energy Science, Technology and Policy (Applied Studies)
- M.S. in Energy Science, Technology and Policy and Integrated Study in Computer Science
- M.S. in Engineering and Technology Innovation Management

Biomedical Engineering

- B.S. in an engineering discipline with an additional major in Biomedical Engineering (p.)
- M.S. in Biomedical Engineering
- M.S. in Biomedical Engineering and Integrated Study in Computer Science
- Ph.D. in Biomedical Engineering
- Ph.D. in Biomedical Engineering and Engineering and Public Policy

Chemical Engineering

- B.S. in Chemical Engineering (p.)
- M. of Chemical Engineering
- M. of Chemical Engineering & Colloids, Polymers and Surfaces
- M.S. in Chemical Engineering
- M.S. in Chemical Engineering and Colloids, Polymers and Surfaces
- M.S. in Chemical Engineering and Integrated Study in Computer Science
- M.S. in Colloids, Polymers and Surfaces
- Ph.D. in Chemical Engineering

Civil and Environmental Engineering

- B.S. in Civil Engineering (p. 117)
- B.S. in Environmental Engineering (p.)
- M.S. in Advanced Infrastructure Systems
- M.S. in Civil Engineering
- M.S. in Civil and Environmental Engineering
- M.S. in Civil & Environmental Engineering and Integrated Study in Computer Science
- M.S. in Civil and Environmental Engineering/M. of Business Administration (jointly with the Tepper School of Business)
- M.S. in Computational Mechanics
- M.S. in Environmental Engineering
- M.S. in Environmental Management and Science
- Ph.D. in Advanced Infrastructure Systems
- Ph.D. in Civil Engineering
- Ph.D. in Civil and Environmental Engineering
- Ph.D. in Civil and Environmental Engineering and Engineering and Public Policy (jointly with the Department of Engineering and Public Policy)
- Ph.D. in Computational Mechanics
- Ph.D. in Environmental Engineering
- Ph.D. in Environmental Management and Science

Electrical and Computer Engineering

- B.S. in Electrical and Computer Engineering (p. 128)
- B.S. in Music and Technology (jointly with the Department of Music and the School of Computer Science)
- M.S. in Electrical and Computer Engineering
- M.S. in Electrical & Computer Engineering and Integrated Study in Computer Science
- M.S. in Software Engineering (Silicon Valley Campus)
- Master of Science in Software Engineering - Development Management (Silicon Valley Campus)
- Ph.D. in Electrical and Computer Engineering

Engineering and Public Policy

- B.S. in an engineering discipline with an additional major in Engineering and Public Policy (p. 145)
- B.S. in CFA, DC, MCS, or SCS and an additional major in Science, Technology and Public Policy (p. 146)
- M.S. in Engineering and Public Policy
- Ph.D. in Engineering and Public Policy
- Ph.D. in Engineering and Public Policy and an engineering discipline
- Ph.D. in Engineering & Public Policy and Language & Information Technologies
- Ph.D. in Engineering and Public Policy and Statistics (jointly with the Department of Statistics)

Information and Communication Technology

- M.S. in Information Technology (CMU Africa campus only)

Information Networking Institute

- M.S. in Information Networking
- M.S. in Information Security
- M.S. in Information Technology - Information Security
- M.S. in Information Technology - Mobility
- M.S. in Information Technology - Software Management

Materials Science and Engineering

- B.S. in Materials Science and Engineering (p. 159)
- M.S. in Additive Manufacturing
- M.S. in Computational Materials Science and Engineering
- M.S. in Materials Science
- M.S. in Materials Science and Engineering
- M.S. in Materials Science & Engineering and Integrated Study in Computer Science
- Ph.D. in Materials Science
- Ph.D. in Materials Science and Engineering

Mechanical Engineering

- B.S. in Mechanical Engineering (p. 171)
- M.S. in Computational Design and Manufacturing
- M.S. in Mechanical Engineering
- M.S. in Mechanical Engineering - Advanced Study
- M.S. in Mechanical Engineering - Research
- Ph.D. in Mechanical Engineering

College of Fine Arts

Architecture

- B. of Architecture (p. 217) (5-year program)
- B.A. in Architecture
- M. of Advanced Architectural Design
- M. of Architecture
- M.S. in Architecture
- M.S. in Building Performance and Diagnostics
- M.S. in Computational Design
- M.S. in Sustainable Design
- M.S. in Sustainable Design (Advanced Studies)
- M.S. in Sustainable Design (Applied Studies)
- M. of Tangible Interaction Design
- M. of Urban Design
- D. of Professional Practice in Advanced Architectural Design

- D. of Professional Practice in Architecture
- Ph.D. in Architecture
- Ph.D. in Building Performance and Diagnostics
- Ph.D. in Computational Design

Art

- B.F.A. in Art (p. 249)
- M.F.A. in Art

Design

- B. of Design (p. 268)
- M.A. in Design
- M. of Design in Design for Interactions
- M. of Design in Interaction Design
- M. of Professional Studies in Design for Interactions
- D. of Design
- Ph.D. in Communication De
- Ph.D. in Design

Drama

- B.F.A. in Drama (p. 288)
- M.F.A. in Costume Design
- M.F.A. in Costume Production
- M.F.A. in Directing
- M.F.A. in Dramatic Writing
- M.F.A. in Lighting Design
- M.F.A. in Scene Design
- M.F.A. in Sound Design
- M.F.A. in Stage and Production Management
- M.F.A. in Technical Direction
- M.F.A. in Video and Media Design

Music

- B.F.A. in Music (Composition) (p. 323)
- B.F.A. in Music Performance (p. 323) (various disciplines)
- B.S. in Music and Technology (p. 328) (jointly with the Department of Electrical and Computer Engineering and the School of Computer Science)
- M. Music in Composition
- M. Music in Music Education
- M. Music in Performance (various disciplines)
- M.S. in Music and Technology (jointly with the Department of Electrical and Computer Engineering and the School of Computer Science)

Dietrich College of Humanities and Social Sciences

Interdepartmental

- B.A./B.S.in Ethics, History, and Public Policy (p. 536) (jointly offered by the Departments of History and Philosophy)
- B.S. in Information Systems (p. 443)
- B.A. in Linguistics (p. 538) (jointly offered by the Departments of English, Languages, Cultures, and Applied Linguistics, Philosophy, and Psychology)
- B.S. in Neuroscience (p. 891) (jointly offered by the Department of Biological Sciences and the Center for the Neural Basis of Cognition)
- B.S. in Psychology and Biological Sciences (p. 539) (jointly offered by the Departments of Psychology and Biological Sciences)
- B.S. in Statistics and Machine Learning (p. 518) (jointly offered by the Department of Statistics and Data Science and the School of Computer Science)

CARNEGIE MELLON INSTITUTE FOR STRATEGY AND TECHNOLOGY

- B.S. in International Relations and Political Science
- B.S. in Political Science, Security, and Technology
- B.S. in Economics and Politics (p.   )
- M.S. in Security, Technology, and International Relations
- Master of Information Technology Strategy

Center for the Neural Basis of Cognition

- Ph.D. in Neural Computation
- Ph.D. in Neural Computation and Machine Learning
- Ph.D. in Neural Computation and Statistics

English

- B.A. in Creative Writing (p. 367)
- B.A. in Film and Visual Media (p. 368)
- B.A. in Literature and Culture (p. 370)
- B.A. in Professional Writing (p. 372)
- B.S. in Technical Writing (p. 373)
- M.A. in Global Communication and Applied Translation
- M.A. in Literary and Cultural Studies
- M.A. in Professional Writing
- M.A. in Rhetoric
- Ph.D. in Literary and Cultural Studies
- Ph.D. in Rhetoric

History

- B.A. in Global Studies (p. 415)
- B.A./B.S. in Social and Political History (p. 412)
- M.A. in History
- Ph.D. in History

Languages, Cultures, and Applied Linguistics

- B.A. in Chinese Studies (p.   )
- B.A. in French and Francophone Studies (p.   )
- B.A. in German Studies (p.   )
- B.A. in Hispanic Studies (p.   )
- B.A. in Japanese Studies (p.   )
- B.A. in Russian Studies (p.   )
- M.A. in Applied Second Language Acquisition
- M.A. in Second Language Acquisition
- Ph.D. in Second Language Acquisition

Philosophy

- B.A. in Philosophy (p. 455)
- B.S. in Logic and Computation (p. 454)
- M.A. in Philosophy
- M.S. in Logic, Computation and Methodology
- Ph.D. in Logic, Computation and Methodology
- Ph.D. in Philosophy
- Ph.D. in Pure and Applied Logic

Psychology

- B.A./B.S. in Psychology (p. 472)
- B.S. in Cognitive Science (p. 476)
- Ph.D. in Cognitive Neuroscience
- Ph.D. in Psychology
- Ph.D. in Psychology and Behavioral Decision Research (jointly with the Department of Social and Decision Sciences)

Social and Decision Sciences

- B.S. in Behavioral Economics (p. 492)
- B.S. in Decision Science (p. 494)
- B.S. in Policy and Management (p. 495)
- M.S. in Behavioral Decision Research
- M.S. in Social and Decision Sciences
- Ph.D. in Behavioral Decision Research
- Ph.D. in Behavioral Economics (jointly with Tepper School of Business)
- Ph.D. in Behavioral Marketing and Decision Research (jointly with Tepper School of Business)
- Ph.D. in Psychology and Behavioral Decision Research (jointly with the Department of Psychology)
- Ph.D. in Social and Decision Sciences

Statistics and Data Science

- B.S. in Statistics (p. 506)
- B.S. in Statistics (Mathematical Sciences Track) (p. 510)
- B.S. in Statistics (Statistics and Neuroscience Track) (p. 513)
- B.S. in Statistics and Machine Learning (p.) (jointly with the School of Computer Science)
- B.S. in Economics and Statistics (p. 533)
- M. of Statistical Practices
- Ph.D. in Neural Cognition and Statistics (jointly with the Center for the Neural Basis of Cognition)
- Ph.D. in Statistics
- Ph.D. in Statistics and Engineering and Public Policy (jointly with the Department of Engineering and Public Policy)
- Ph.D. in Statistics and Machine Learning (jointly with the Department of Machine Learning)
- Ph.D. in Statistics and Public Policy (jointly with the Heinz College)

Heinz College of Information Systems and Public Policy

Information Security

- M.S. in Information Security Policy and Management

Information Systems

- M. of Information Systems Management
- M. of Information Systems Management in Business Intelligence and Data Analytics
- Ph.D. in Information Systems and Management

Information Technology

- M.S. in Information Technology (Business Intelligence and Data Analytics)
- M.S. in Information Technology (IT Management)
- M.S. in Information Technology (Information Security and Assurance)
- M.S. in Information Technology (Software Design and Management)

Arts Management

- M. of Arts Management (jointly with the College of Fine Arts)
- M. of Arts Management (jointly with the College of Fine Arts) and J.D. (jointly with the University of Pittsburgh School of Law)

Entertainment Industry Management

- M. of Entertainment Industry Management (jointly with the College of Fine Arts)

Health Care Policy and Management

- M.S. in Health Care Analytics and Information Technology

Medical Management

- M. of Medical Management

Public Management

- M. of Public Management

Public Policy and Management

- M.S. in Public Policy and Management
- M.S. in Public Policy and Management (Data Analytics)
- M.S. in Public Policy and Management and M.B.A. (jointly with Tepper School of Business)
- M.S. in Public Policy and Management and J.D. (jointly with the University of Pittsburgh School of Law)
- M.S. in Public Policy and Management and M. of Divinity (jointly with the Pittsburgh Theological Seminary)
- Ph.D. in Economics and Public Policy (jointly with the Tepper School of Business)
- Ph.D. in Machine Learning and Public Policy (jointly with the School of Computer Science)
- Ph.D. in Public Policy and Management
- Ph.D. in Statistics and Public Policy (jointly with Dietrich College of Humanities and Social Sciences)

Mellon College of Science

Interdepartmental

- B.S. in Mathematical Sciences and Economics (jointly offered by the Department of Mathematical Sciences and the Undergraduate Economics Program)
- Ph.D. in Molecular Biophysics and Structural Biology

Biological Sciences

- B.A. in Biological Sciences (p. 571)
- B.S. in Biological Sciences (p. 568)
- B.S. in Biological Sciences/Neuroscience Track (p. 570)
- B.S. in Biological Sciences and Psychology (p. 571) (jointly with the Department of Psychology)
- B.S. in Neuroscience (p. 571) (jointly with the Department of Psychology)
- M.S. in Biological Sciences
- Ph.D. in Biological Sciences

Chemistry

- B.A. in Chemistry (p. 589)
- B.S. in Chemistry (p. 586)
- B.S. in Chemistry/Biological Chemistry Track (p. 591)
- M.S. in Chemistry
- M.S. in Colloids, Polymers, and Surfaces (jointly with the Department of Chemical Engineering)
- Ph.D. in Chemistry

Mathematical Sciences

- B.S. in Mathematical Sciences (p. 618)
- M.S. in Algorithms, Combinatorics, and Optimization
- M.S. in Mathematical Sciences
- M.S. in Computational Finance (jointly with the Department of Statistics, the H. John Heinz III College, and the Tepper School of Business)
- D.A. in Mathematical Sciences
- Ph.D. in Algorithms, Combinatorics, and Optimization
- Ph.D. in Mathematical Finance
- Ph.D. in Mathematical Sciences
- Ph.D. in Pure and Applied Logic (jointly with the Department of Philosophy and the School of Computer Science)

Physics

- B.A. in Physics (p. 644)
- B.S. in Physics (p. 642)
- M.S. in Physics
- Ph.D. in Applied Physics
- Ph.D. in Physics

School of Computer Science

ARTIFICIAL INTELLIGENCE

- B.S. in Artificial Intelligence (p. 674)

Computer Science

- B.S. in Computer Science (p. 683) (jointly with the Institute for Software Research)
- B.S. in Music and Technology (p. 328) (jointly with the Departments of Electrical and Computer Engineering and Music)
- M.S. in Computer Science
- M.S. in Computer Science - Foundational Studies
- M.S. in Computer Science - Research
- M.S. in Computer Science - Research Thesis
- M.S. in Computer Science (5th Year Scholars Program only)
- Ph.D. in Algorithms, Combinatorics and Optimization (jointly with the Department of Mathematical Sciences and Tepper School of Business)

- Ph.D. in Computer Science
- Ph.D. in Pure and Applied Logic (jointly with the Department of Mathematical Sciences and the Department of Philosophy)

Computational Biology Department

- B.S. in Computational Biology (p. 679)
- M.S. in Automated Science - Biological Experimentation
- M.S. in Computational Biology
- Ph.D. in Computational Biology

Human-Computer Interaction

- B.S. in Human-Computer Interaction (p. 688)
- M. of Human-Computer Interaction
- M. of Human-Computer Interaction (5th Year Scholars Program only)
- M. of Educational Technology & Applied Learning Sciences (jointly with the Dietrich College of Humanities and Social Sciences)
- M.S. in Product Management (jointly with Tepper School of Business)
- Ph.D. in Human-Computer Interaction

Institute for Software Research

- M. of Software Engineering in Embedded Systems
- M. of Software Engineering in Scalable Systems
- M. of Software Engineering in Software Engineering
- M.S. in Information Technology - Privacy Engineering
- Ph.D. in Societal Computing
- Ph.D. in Software Engineering

Language Technologies Institute

- M.S. in Artificial Intelligence and Innovation
- M.S. in Intelligent Information Systems
- M.S. in Intelligent Information Systems - Advanced Study
- M.S. in Language Technologies
- M. of Computational Data Science
- Ph.D. in Language and Information Technologies

Machine Learning

- M.S. in Machine Learning
- M.S. in Machine Learning (5th Year Scholars Program only)
- Ph.D. in Machine Learning
- Ph.D. in Machine Learning & Public Policy (jointly with the Heinz College)
- Ph.D. in Neural Computation and Machine Learning (jointly with Center for Neural Basis of Cognition)
- Ph.D. in Statistics and Machine Learning (jointly with the Dietrich College of Humanities and Social Sciences)

Robotics Institute

- B.S. in Robotics (http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/robotics/)
- M.S. in Computer Vision
- M.S. in Robotics
- M.S. in Robotics (5th Year Scholars Program only)
- M.S. in Robotic Systems Development
- Ph.D. in Robotics

David A. Tepper School of Business

Business Administration

- B.S. in Business Administration (p. 847)

Economics

- B.A. in Economics (p. 867)
- B.S. in Economics (p. 868)
- B.S. in Economics and Mathematical Sciences (p. 869)

Industrial Administration

- M. of Business Administration (M.B.A.)
- M.B.A./M.S. in Public Policy Management (jointly with Heinz College)
- M.B.A./M.S. in Civil and Environmental Engineering (in association with Carnegie Institute of Technology)
- M.B.A. and J.D. in Law (jointly with the University of Pittsburgh Law School)
- M.B.A/M.S. in Health Care Policy Management (jointly with Heinz College)
- M.B.A/M.S in Software Engineering (jointly with the School of Computer Science)
- M.S. in Business Analytics
- M.S. in Computational Finance (jointly with Dietrich College, the Mellon College of Science, and Heinz College)
- M.S. in Product Management
- Ph.D. in Accounting
- Ph.D. in Algorithms, Combinatorics, and Optimization (jointly with the School of Computer Science and Department of Mathematical Sciences)
- Ph.D. in Economics
- Ph.D. in Finance
- Ph.D. in Information Systems
- Ph.D. in Management of Manufacturing and Automation (with Robotics Institute)
- Ph.D. in Marketing
- Ph.D. in Operations Management and Manufacturing
- Ph.D. in Operations Research
- Ph.D. in Organizational Behavior and Theory
- Ph.D. in Economics and Public Policy (jointly with Heinz College)
- Ph.D. in Strategy, Entrepreneurship, and Technological Change (jointly with the Department of Social and Decision Sciences, Heinz College, and the Department of Engineering and Public Policy)

University-Wide, Interdisciplinary, and Joint Degree Programs

Architecture-Engineering-Construction Management Program

- M.S. in Architecture-Engineering-Construction Management (jointly with the Department of Civil and Environmental Engineering and the School of Architecture)
- Ph.D. in Architecture-Engineering-Construction Management (jointly with the Department of Civil and Environmental Engineering and the School of Architecture)

BXA Intercollege Degree Programs

- B. of Computer Science and Arts (p.) (jointly with the School of Computer Science and the College of Fine Arts)
- B. of Engineering Studies and Arts (p. 899) (jointly with the College of Engineering and the College of Fine Arts)
- B. of Humanities and Arts (p.) (jointly with the Dietrich College of Humanities and Social Sciences and the College of Fine Arts)
- B. of Science and Arts (p.) (jointly with the Mellon College of Science and the College of Fine Arts)
- B.S. in an engineering discipline with an additional major in Engineering and Arts (p. 930) (jointly with the College of Engineering and College of Fine Arts)

Communication Planning and Information Design Program

- M. Design in Communication Planning and Information Design (jointly with the School of Design and the Department of English)

Computational Finance Program

- B.S. in Computational Finance (p. 881) (jointly with the Dietrich College of Humanities and Social Sciences, Heinz College, Mellon College of Science and Tepper School of Business)
- M.S. in Computational Finance (jointly with the Dietrich College of Humanities and Social Sciences, Heinz College, Mellon College of Science and Tepper School of Business)

Entertainment Technology Center

- M. of Entertainment Technology

information technology strategy

- Master of Information Technology Strategy (MITS) (https://www.cmu.edu/mits/) (jointly with the College of Engineering, School of Computer Science and the Carnegie Mellon Institute for Strategy and Technology)

Integrated Innovation Institute

- M. of Integrated Innovation for Products and Services
- M. of Integrated Innovation for Products and Services - Advanced Study
- M.S. in Software Management (Silicon Valley campus)

Science and Humanities Scholars Program

- B.A./B.S. in various disciplines (p.) (jointly with the Dietrich College of Humanities and Social Sciences and the Mellon College of Science)

Carnegie Mellon University in Qatar

Qatar Biological Sciences

- B.S. in Biological Sciences

Qatar Business Administration

- B.S. in Business Administration

Qatar Computer Science

- B.S. in Computer Science
- B.S. in Computational Biology

Qatar Information Systems

- B.S. in Information Systems

Schools/Colleges

The intersection of fields is a Carnegie Mellon University specialty. Renowned faculty at the university's seven schools/colleges explore side by side with students, collaborating on research, tackling society's biggest challenges and delivering work that matters. In addition to the hundreds of programs offered by the schools and colleges, CMU also offers dozens of interdisciplinary programs (p. 881), which are designed especially for students who want to work beyond just one discipline.

College of Engineering

William H. Sanders, Dr. William D. and Nancy W. Strecker Dean of the College of Engineering &
Professor, Electrical and Computer Engineering

Conrad Zapanta Ph.D, Associate Dean for Undergraduate Studies and Teaching Professor in Biomedical Engineering

Kurt Larsen, Assistant Dean for Undergraduate Studies

Treci Bonime, Assistant Dean for Undergraduate Studies

Location: ANSYS Hall, 2nd floor
https://engineering.cmu.edu

Carnegie Institute of Technology (CIT), the engineering college of the university, has three main activities - undergraduate education, graduate education, and research. Its continuing goal has been to maintain excellence in all these activities. The degree to which this goal has been achieved is attested to by the demand for its graduates, the success of its alumni, the quality of its students and faculty, the adoption elsewhere of its innovations, and the national and international recognition it receives in educational and research activities.

The college offers the degree of bachelor of science in chemical engineering, civil engineering, electrical and computer engineering, environmental engineering, mechanical engineering, and materials science and engineering.

An engineering student may also choose to pursue a minor in one of the CIT designated minor programs, or an additional major in engineering and public policy, biomedical engineering or engineering design, innovation & entrepreneurship. Engineering students can also design a minor, additional major or dual-degree programs with other non-engineering departments.

Educational Objectives

The overarching objective of our engineering curriculum is to provide our students an education that enables them to be productive and fulfilled professionals throughout their careers. Our more specific, measurable objectives for graduates of our engineering curriculum are the following:

- Graduates recognize that they acquired a high quality, rigorous technical education from the College of Engineering at Carnegie Mellon.
- Graduates, in addition to their technical knowledge, recognize that they have acquired a broader body of knowledge that allows them to understand the larger context of the problems that they must address during their career.
- Graduates use their technical foundation and their broader base of knowledge to be successful in a diverse collection of individual careers inside and outside of the engineering profession.

From its earliest days, Carnegie Institute of Technology (CIT) has considered undergraduate education to be the key element in the development of future leaders. In this regard, CIT has adopted a plan for education that is designed to equip students with the capacity to learn and to continue the process of self-education throughout their lives. The present curriculum incorporates this philosophy by providing the opportunity for both breadth in a number of engineering, science, humanities and fine arts areas as well as depth in a major area of concentration. To achieve these goals, our flexible curriculum has been designed to allow students to customize their program to suit their needs and to help each student acquire:

- A thorough and integrated understanding of fundamental knowledge in fields of a students' major interest and the ability to use this knowledge;
- Competence in the orderly way of thinking, which professionals and scientists have always used in reaching sound, creative conclusions, with the goal that after graduation the student can, by such thinking, reach decisions both as a professional and as a citizen;
- An ability to learn independently with scholarly orderliness, so that after graduation the student will be able to grow in wisdom and keep abreast of the changing knowledge and problems of the profession and the society in which he or she participates;
- The philosophical outlook, breadth of knowledge, and sense of values which will increase the student's understanding and enjoyment of life and enable each student to recognize and deal effectively with the human, economic, ethical and social aspects of professional problems; and
- The ability to communicate ideas to others in a comprehensive and understandable manner.

The curriculum encourages students to confront professional problems, accomplished through team and problem-oriented courses, as well as courses which emphasize design or individual projects. These classes stress creativity and independent thought and require the student to define the problem, propose a solution or a design in the presence of technical and socioeconomic constraints, to make judgments among alternative solutions, and to explore innovative alternatives to more conventional solutions.

First Year for Engineering Students

The Carnegie Mellon engineering education is based on engineering and science fundamentals that give students the skills to face new and challenging situations. The first year in engineering provides a broad foundation upon which students build a curriculum in their eventual major. Since students in CIT do not select a major until the end of the first year, all first year students share a common experience consisting of introductory courses in the engineering majors (one each semester), calculus, physics, other science courses which complements specific introductory engineering courses, and courses in the liberal arts, fine arts, business, and social sciences. This curriculum helps make an informed decision about a final major. Below is an examples of a standard schedule for a first-year engineering student.

Fall Semester	
Introductory Engineering Elective	12
Restricted Technical Elective	9-12
Differential and Integral Calculus	10
General Education	9
Computing @ Carnegie Mellon	3

Spring semester	
Introductory Engineering Elective	12
Restricted Technical Elective	10
Integration, Differential Equations, Approximation	10
General Education Course	9

Notes:

1. Each semester every CIT department offers its Introductory Engineering Elective. Every first year CIT student must select one such course each semester.

2. Each Introductory Engineering Elective requires a specific Restricted Technical Elective as given below. Restricted Technical Electives are foundational science courses relevant to engineering degrees.

Introductory Engineering Course	Restricted Technical Elective
Biomedical Engineering	**03-121**
Chemical Engineering	**09-105**
Civil & Environmental Engineering	**33-141**
Electrical & Computer Engineering	**15-110 or 15-112**
Engineering & Public Policy	**33-141**
Mechanical Engineering	**33-141**
Materials Science & Engineering	**33-141**

3. All students must complete 33-141 Physics I for Engineering Students by the end of the first year. Therefore, if a student chooses to take Introduction to Chemical Engineering (with 09-105 as a co-requisite) during one semester and Introduction to Electrical and Computer Engineering (with 15-110 as a co-requisite), the student must take 33-141 in place of the General Education requirement in the Spring semester of the first year and take the General Education course in a subsequent semester. Alternatively, a student entering the university with AP credit in a required first year course may substitute 33-141 in its place.

4. CIT students must complete the First-Year Writing requirement in their freshman year. View more information (p. 84).

General Education Programs

The environment in which today's engineering graduates will find themselves working is evolving rapidly. Technical innovation is becoming ever more critical to retaining a competitive edge. This is true for individuals, for firms and for nations. Start-ups, as well as established companies, have significant international opportunities but also face more competition in a global economy. Seizing these opportunities and dealing with the associated challenges requires an understanding of the global context in which engineers work, as well as understanding multi-disciplinary approaches to technological innovation across cultures.

The College of Engineering has developed General Education Requirements designed to ensure that our students are ready to work effectively in the global economy, and become the innovators and leaders of tomorrow.

CIT General Education Requirements

All undergraduate students must complete the First-Year Writing requirement — **the Department of English does not accept any Advanced Placement exemptions.** This requirement can be completed in two different ways:

Option 1: Enroll in one of two full-semester courses (9 units each)
76-101 Interpretation and Argument (Students for whom English is a second language may need to take 76-100 Reading and Writing in an Academic Context first. The English department will contact those students.)
76-102 Advanced First Year Writing: Special Topics: (by invitation only)

Option 2: Enroll in two of three half-semester "mini" courses* (4.5 units each)
76-106 Writing about Literature, Art and Culture:
76-107 Writing about Data
76-108 Writing about Public Problems

*Minis should be completed back-to-back within a single semester.

General Education Electives (3 total)

At least 27 units from any non-technical academic courses from the Dietrich College, College of Fine Arts, and the Tepper School of Business excluding those listed on the General Education Exclusions page (https://engineering.cmu.edu/education/undergraduate-programs/curriculum/general-education/exclusions.html). Courses from this list of non-technical courses outside of the Dietrich College or the College of Fine Arts (https://engineering.cmu.edu/education/undergraduate-programs/curriculum/general-education/non-dietrich-cfa-courses.html#undefined) may also be counted. **A maximum of 18 units of these units may be fulfilled via AP/IB/Cambridge exam credit.**

For category course lists reference the CIT General Education website (https://engineering.cmu.edu/education/undergraduate-programs/curriculum/general-education/).

General Education Categories

Students must complete each of the categories (descriptions of categories follow below). This is a 9-unit requirement. Any course taken on this list that is below 9 units must be combined with an additional course to total at least 9 units in order to complete this requirement.

Note that the units from one course cannot be split to count for two General Education categories (eg PPC and General Education Elective).

- **Innovation & Internationalization (I&I)**
  - 9 units from the I&I list of courses (which could be two 4.5 unit courses);
- **Peoples, Places, and Cultures (PPC)** [1]
  - 9 units from the PPC list; (Students can receive exemption through an approved study abroad program. These students would have three General Education Electives to complete instead of two.)
- **Social Analysis and Decision Making (SDM)**
  - 9 units from the SDM list of courses (which could be two 4.5 unit courses)
- **Writing and Expression (W&E)**
  - 9 units from the W&E list of courses (in addition to 76-101)

Experiential Learning (EL)

- 6 EL points by participating in a variety of approved activities in the following timeframe:
  - 2 points sophomore fall semester (39-210)
  - 2 points sophomore spring semester (39-220)
  - 2 points junior fall semester (39-310)

Category Descriptions

People, Places and Cultures (PPC)

PPC courses are designed to help you gain better understanding of the diversity of the world in which we live, and the way in which societal factors interact to shape that world.

Social Analysis and Decision Making (SDM)

SDM courses are focused on helping you to gain an understanding of different ways in which individuals and societies approach and make decisions.

Innovation and Internationalization (I&I)

I&I courses are intended to provide a broad perspective regarding the creation of pioneering ideas and their outcomes in a global context.

Experiential Learning (EL)

Being curious and constantly looking for inspiration are critical parts of lifelong learning. To be successful as an engineer and as a citizen, your education must not stop when you graduate from Carnegie Mellon. The EL requirement aims to encourage a habit of lifelong learning about innovation and the growing internationalization in engineering and, indeed of many other aspects of the modern world. The goal of this requirement is to help inspire the habits of being open to new ideas as successful, innovative engineers.

To do that, during both semesters of your sophomore year, and the first semester of your junior year, we require you to choose a few related activities that are not part of your formal course work. Examples could include:

- Attending approved seminars and then submitting a one page write up of your thoughts on what you heard;
- Holding an official leadership position (i.e., President, Vice President, Secretary, Treasurer) in a Carnegie Mellon sponsored organization

Additional Majors, Dual Degrees & Minors

A major is defined as a program that must be completed for the granting of a degree. Additional majors comprise a single degree with majors in two separate areas; for example, the degree of Bachelor of Science in Chemical Engineering and an additional major in English. Although the additional major requires the completion of two designated programs, they may have overlapping requirements that can be met simultaneously. The general principle used to measure eligibility for a College of Engineering additional major is that the major (core) requirements of both departments must be completed. Finally, although the student is formally enrolled as an undergraduate in one of the departments (the parent department, which is responsible for scheduling and other administrative actions for the student), the student should apply for the additional major through the second department and coordinate requirements with both departments.

The additional major is to be distinguished from a dual degree program, which results in two separate bachelor's degrees; for example, Bachelor of Science in Chemical Engineering and a Bachelor of Arts in English. The dual degree, though, requires a minimum of 90 units of work in addition to the units required for the first degree. The second degree may be earned in Bachelor of Science or Bachelor of Arts degree programs.

Requirements for students wishing to complete Additional Majors in CIT

*Note: This applies to **all** students.*

The student must satisfactorily pass all requirements of the regular and complete program (with the permissible exceptions) leading to a degree in CIT. The minimum number of units required for the additional major is the number required by the parent department or major.

The student takes and satisfactorily completes the courses specified by a second department, usually using elective space available in the first program.

The second department, on the basis of the specified number of courses plus the courses comprising the parent department's regular degree requirements, then certifies that the student has completed the requirements for a major in the second department.

Equivalent technical electives may be substituted at the discretion of the departments/colleges.

Non-technical courses in the curricula can be used to meet the requirements of the second major. But if the second major is not a Dietrich College department, the program must include a minimum of 72 units of General Education courses to meet CIT requirements for graduation.

Bachelor of Engineering Studies and Arts (BESA Program)

The Bachelor of Engineering Studies and Arts (BE (p. 894)SA) intercollege degree program (p. 894) combines the strengths of the College of Fine Arts (CFA) and the College of Engineering (ENG). This degree is tailored for students seeking to apply knowledge from duel fields to advance maker culture in novel and creative ways. Students choose their arts concentration from the following schools in CFA: Architecture, Art, Design, Drama or Music. Students choose their engineering studies concentration established by the College of Engineering. Options within the concentration include: biomedical engineering, chemical engineering, civil & environmental engineering, electrical & computer engineering, materials science & engineering or mechanical engineering.

The BESA curriculum has three main components: general education requirements, fine arts concentration requirements and engineering studies concentration requirements. Each student's course of study is structured so they can complete this rigorous program in four years.

Students receive extensive advising support. The academic advisors in the BXA Intercollege Degree Programs are the primary advisors and liaisons between CFA and ENG. Each student has two additional academic advisors: an advisor in the admitting school of CFA to guide their focus in the arts and an advisor in ENG to guide their focus in engineering studies. Please reference the Internal Transfer (https://www.cmu.edu/interdisciplinary/apply/internal-transfer.html) process.

Biomedical Engineering

The Biomedical Engineering additional major program (http://coursecatalog.web.cmu.edu/schools-colleges/collegeofengineering/departmentofbiomedicalengineering/#coursestext) takes advantage of curricular overlaps between Biomedical Engineering and traditional engineering majors, such that the additional major can be completed in four years with only a modest increase in course requirements. The requirements for Biomedical Engineering consist of the core, the tracks, and the capstone design course. The core exposes students to basic facets of biomedical engineering to lay a foundation. The tracks allow students to build depth in a specific aspect of biomedical engineering. The capstone design (https://www.cmu.edu/bme/Academics/undergraduate-programs/Resources/undergrad_design.html) engages students in teamwork to develop real-world applications. The additional major in Biomedical Engineering should be declared at the same time when declaring a traditional engineering major.

Student majoring in Biomedical Engineering must meet three sets of requirements: 1) Biomedical Engineering 2) Traditional engineering discipline 3) CIT General Education (http://www.cit.cmu.edu/current_students/services/general_education.html) sequence. The Quality Point Average (QPA) for courses that count toward the additional major must be 2.00 or higher. No course taken on a pass/fail or audit basis may be counted toward the additional major.

Engineering and Arts Additional Major

The Engineering and Arts (EA) additional major (p. 894) is intended for College of Engineering students who also have interest and talent in an arts concentration (architecture, art, drama or music) and goals that can only be accomplished at the intersection of those disciplines.

EA applications are considered every semester, with a deadline of mid-semester break for admission in the following semester. (See below for exceptions.) Along with the application, our additional major committee also considers prior semester grades and mid-semester grades for the semester of application. Decisions are sent out in advance of registration for the following semester.

The application includes an Essay of Interdisciplinary Intent, in which a student explains why they're interested in the two areas and why they want to combine them. This essay should be brief—500 words or fewer—and specific about both a student's background in the concentration areas and what their goals are for bringing them together.

Completing an additional major demands advanced planning and preparation to determine the most appropriate semester to take requirements. All students applying for EA must meet with their current Engineering advisor, the BXA director and an advisor in their target CFA area, as well as take preliminary coursework in their target area before submitting the application (https://www.cmu.edu/interdisciplinary/apply/additional-major.html).

Engineering Design, Innovation, and Entrepreneurship Additional Major (EDIE Program)

Overview

As humanity grapples with dilemmas of extraordinary complexity throughout the globe, our world needs engineers who are leaders and change makers. Our world needs engineers who seek to push the boundaries in their education, and carry their passion for technological innovation forward.

The Engineering Design, Innovation, and Entrepreneurship (EDIE) additional major will provide students the know-how to innovate products around that technology and deliver product solutions to the people who need them.

EDIE students will have expertise in technology and the ability to design, develop, and deliver economically viable solutions to the real-world challenges of today and tomorrow.

Curriculum Details

The EDIE additional major isn't just for students who want to create a startup—it will help to prepare hands-on, get-it-done leaders who are in demand in all sectors of society and industry, for-profit and not-for-profit. Given the applied focus of our curriculum, courses will equip our students with mindsets, skills, and capabilities to identify and shape opportunities and develop economically sustainable solutions.

Students in the EDIE additional major must also satisfy the core requirements of their primary major typically following the standard schedule of courses each semester. EDIE core requirements are fulfilled in addition to the course requirements of their primary major, mainly using various elective units. The side-by-side curriculum charts for each primary major show how the requirements for the stand-alone majors and the primary major plus EDIE additional major compare.

Course Requirements

Introductory Course
49-101 Engineering Design, Innovation and Entrepreneurship (12 units)

Engineering Design and Innovation Courses
49-305 Customer Discovery for Tech Innovation (4.5 units)
49-306 Engineering Design Methods & Tools (4.5 units)
49-405 Leading Engineering Innovation Teams (4.5 units)

Engineering Entrepreneurship Courses
49-205 Tech Venture Marketing for Engineers (4.5 units)
49-206 Tech Business Planning (4.5 units)
49-406 Tech Venture Formation (4.5 units)

Foundation Skills Courses
73-102 Principles of Microeconomics (9 units)
70-345 Business Presentations (9 units)

Home Department Engineering Design Capstone (12 units)

Please consult with your home engineering department to confirm the specific Engineering Design Capstone course(s) that apply to your primary engineering degree. 12 units will count towards your EDIE degree requirements.

49-420 EDIE Innovation Capstone Course (9 units)
49-421 EDIE Entrepreneurship Capstone Course (9 units)

Engineering and Public Policy

The EPP department (http://coursecatalog.web.cmu.edu/schools-colleges/collegeofengineering/departmentofengineeringandpublicpolicy/courses/) offers additional major B.S. degree programs with each of the five traditional engineering departments in the engineering college. The engineering additional major leads to a fully accredited engineering degree that prepares students for traditional technical career. EPP additional major engineers are not educated to be a different kind of engineer. Rather their education is intended to enable them to be better, more socially responsible engineers in the traditional technical fields.

Students who earn an additional major in Engineering and Public Policy at the undergraduate level do so in conjunction with a traditional engineering major. The elements of the EPP undergraduate program broaden the traditional scope of technical analysis to encompass an engineering solution's potential impact on society. Thus, our graduates have the same skills as their peers in traditional engineering majors, but with a broader societal perspective and additional analysis skills. This enables our graduates to understand the interface between technology and society and to help solve the complex, interdisciplinary systems problems facing our world, in their careers. Students will be able to work in a variety of career fields, including technical and non-technical, in industry, government, or elsewhere where these broad skills are needed.

Designated Minors for Engineering Students

Undergraduate students in the College of Engineering can elect to complete an interdisciplinary Designated Minor in addition to their primary major. Designated minors have been added to the curriculum to provide the student with technical elective content in areas related to the research expertise of our faculty. Students may select a designated minor from the following list:

- Audio Engineering
- Biomedical Engineering*
- Colloids, Polymers and Surfaces
- Electronic Materials
- Global Engineering
- Information Security, Privacy, and Policy*
- Material Science and Engineering
- Mechanical Behavior of Materials

* Also available for non-CIT students

Complete descriptions of the designated minors can be found at CIT Designated Minors (http://coursecatalog.web.cmu.edu/schools-colleges/collegeofengineering/undergraduatedesignatedminors/.html).

To declare a CIT Designated Minor, please contact the director listed for each minor.

Minors for Non-Engineering Students

Students in a non-engineering discipline can also declare certain CIT minors:

- Biomedical Engineering
- Engineering Studies
- Technology and Policy

A full listing of curriculum for these minors when taken by non-engineering students can be found at CIT Minors for Non-Engineering Students (p. 192).

Academic Standards

Grading Practices

For undergraduate grading regulations, please see Undergraduate Academic Regulations (p. 25).

CIT Dean's Honor List

Each semester, Carnegie Institute of Technology recognizes students who have earned outstanding academic records by naming them on the dean's honor list. The criterion for such recognition is a semester quality point average of at least 3.75 while completing at least 36 factorable units and earning no incomplete grades.

Transfer into CIT Departments

Undergraduate students admitted to colleges other than CIT who wish to transfer into a CIT department during their first year should consult with an advisor in the Undergraduate Studies Office in the CIT Dean's Office.

First-year students can apply for transfer after mid-semester grades for the spring semester have been posted. At that time, a decision will be based on availability of space and the student's academic performance.

CIT undergraduate students beyond the first year wishing to transfer into another CIT department may apply if they are in good academic standing and if there is room in the department of their choice. If the demand for any department exceeds the space available, then the department will admit students based on a comparative evaluation of all applicants at the end of each semester, up to the limit of available space.

Undergraduate students not in CIT who wish to transfer into a CIT department beyond the first year will be considered for transfer on a rolling space available/academic performance basis.

Criteria for all applicants include space in the department, good academic standing, and successful completion of or being currently enrolled in at least one introductory to engineering course (minimally the one of the target major), the appropriate science co-requisite, math (21-120, 21-122) and Physics 1 (33-141, 33-121, or 33-151).

Procedure for transfer of students from another university into CIT departments: A student first applies through the Office of Admission. If the Office of Admission believes the applicant is acceptable, the student's record is sent to the CIT Undergraduate Studies Office for evaluation and a decision on acceptance/rejection is made in consultation with the target department.

Academic Actions

In order to maintain good academic standing, CIT students must attain at least minimum quality point averages for each semester (as well as cumulatively) and also maintain adequate progress toward completing graduation requirements. Minimum QPA (quality point average) for good academic standing is 2.00. "Adequate academic progress towards graduation" generally means that students are successfully completing approximately 45-55 units per semester so that at the end of eight semesters they will have accumulated the minimum units required for graduation, have a cumulative QPA of at least 2.00, and have completed all degree requirements.

In addition to academic actions based on QPA, CIT students may be placed on warning, subsequent suspension or drop, if they do not demonstrate reasonable progress through the core curriculum of their major (e.g., not completing a core class after three attempts). Students are encouraged to consult with their academic advisor about any concerns with regard to lack of progress in their chosen major to determine if any course drop or withdrawal will lead to an action.

When a student fails to meet minimum performance criteria, it results in an academic action. Depending on the circumstances, one of the following actions is taken: academic warning, warning continued, suspension, or drop. These academic actions are recommended by the college's departments, based on the guidelines described below, and adjudicated by the CIT Undergraduate Studies Office. However, the sequence of the academic actions is not automatic in all cases. Decisions may be based on unique individual student performance and circumstances, and are not determined solely on the basis of grades and quality point averages.

Warning

A student is on academic warning when performance either for the semester or cumulatively fails to meet the minimum standard. The term of academic warning is one semester, and signifies to the student the college's insistence that academic performance return to at least the minimum acceptable level.

Students are removed from warning when adequate academic progress* toward completing graduation requirements is being made, and:

- First year students: if the second semester's QPA and fall/spring combined QPA is 2.00 or above
- Students in the third or subsequent semester of study: if the semester QPA and cumulative QPA (excluding the first year) are 2.00 or above

Warning Continued

A student on warning in their third or subsequent semester who earns at least a 2.00 semester QPA is continued on academic warning when cumulative performance (exclusive of first year) is below 2.00.

A first-year student on warning, who earns a semester grade point average above 2.00 but cumulative QPA is below 2.00 will be continued on warning.

Suspension

A first year student on warning, who earns a semester QPA below 2.00 will be suspended.

A student on warning in the third or subsequent semester, who earns a semester QPA below 2.00 will be suspended.

The typical period of academic suspension is two semesters (excluding summer), during which a student on academic suspension is expected to reflect on the circumstances leading up to the suspension, identify the issues that prevented achieving academic success, take actions that address these issues, demonstrate sufficient readiness to return to the university and successfully resume their studies.

Two months prior to the end of that suspension period, a student may petition to return to school (on final warning) by completing the following steps:

- Writing a formal petition, requesting to return and receiving permission in writing from the CIT associate dean for undergraduate studies.
- If approved for return, completing a Return from Leave of Absence form from Enrollment Services; and
- Providing transcripts if the student has been in a program at another college or university even though academic credit earned may not transfer back to Carnegie Mellon University unless prior approval from the associate/assistant dean is given. A maximum of two approved courses may be transferred.

Drop

Students who have been suspended and who fail to meet minimum standards in the subsequent semester(s) after they return to school on warning will be dropped from the College of Engineering.

Students who have been suspended or dropped and are not admitted to another program at the university are required to absent themselves from the campus (including residence halls, office labs, libraries, and Greek houses).

Graduation Requirements and degree certification

To be eligible to graduate, undergraduate students must complete all course requirements for their department with a cumulative Quality Point Average of at least 2.0 for all courses taken. For undergraduate students who enrolled at Carnegie Mellon as freshman and whose freshman grades cause the cumulative QPA to fall below 2.0, this requirement is modified to be a cumulative QPA of at least 2.0 for all courses taken after the freshman year. Note, however, the cumulative QPA that appears on the student's final transcript will be calculated based on all grades in all courses taken, including freshman year. Some departments may have additional QPA requirements in order to graduate. Students are encouraged to confirm all graduation requirements with their academic advisor.

1. All mathematics (21-xxx) courses **required*** for the engineering degree taken at Carnegie Mellon must have a minimum grade of C in order to be counted toward the graduation requirement for the BS engineering degree.

2. A minimum grade of C must be achieved in any required mathematics (21-xxx) course that is a pre-requisite for the next higher level required mathematics (21-xxx) course.

***Elective mathematics courses are not included in this policy**

Students must be recommended for a degree by the faculty of CIT.

A candidate must meet the residence requirement of having completed at least 180 units at Carnegie Mellon University.

Students must meet all financial obligations to the university before being awarded a degree.

Modification of Graduation Requirements: A student may seek permission to modify graduation requirements by petition to the CIT College Council.

Please reference the University's Degree Certification policy (http://coursecatalog.web.cmu.edu/aboutcmu/undergraduateacademicregulations/#degreecertificationtextcontainer). **For engineering students:**

All BS students are expected to complete the BS degree within the standard 8-semester timeline. Units cannot be double counted between BS and MS. Courses taken within the first 8 semesters will first be counted toward completing the BS requirements.

Students who plan to enter an MS program but are unable to complete the BS degree within the 8-semester timeframe can petition to extend their time as an undergraduate. This petition should be addressed to their undergraduate academic advisor and the CIT Undergraduate Dean's Office.

CIT Interdisciplinary Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

39-109 Grand Challenge Freshman Seminar: Climate Change

Fall and Spring: 9 units
Climate change is considered by many the most serious social, political, and environmental issue of the 21st century. As human activities increase the level of greenhouse gases in the atmosphere, scientists have established the reality of climate change and have estimated its impacts on human society and the natural world. Despite the scientific consensus on its existence, causes, and consequences, a substantial number of Americans and citizens of other countries still question these conclusions and a small but vocal group of doubters continue to challenge the science and scientific consensus on climate change. In spite of some social division over these issues, governments at local, national, and international levels have made concerted efforts to craft policies to address climate change. These policies have shifted over time as the information, attitudes, and technology associated with climate change have evolved. In this course, we will explore the challenges and complexities of climate change by investigating the subject from a variety of angles: scientific, political, rhetorical, cultural, economic, technological, and ethical. Over the course of the semester, well inquire: What is climate change? How do scientists know it is happening? Why is there public debate over it? What solutions are available? And what are the pros and cons of the different solutions?

39-135 DC Grand Challenge First-Year Seminar: Designing Better Human-AI Futures

Intermittent: 9 units
This course will explore the societal impacts of artificial intelligence (AI) based decision-making systems, especially focusing on the societal biases they may enhance or reduce. Students will gain a fundamental understanding of how these systems are designed and work, as well as the role of data in mitigating or enhancing biases. The course is multidisciplinary in nature and brings together social scientists, engineers, data scientists, and designers to tackle the grand challenge of dealing with issues of bias and fairness in Human-AI collaborative systems, ranging from the data that is used to train them, to their human creators that are responsible for deciding how they work and get used. Students will investigate policy, technology and societal elements aimed at reducing and mitigating the impact of AI biases that can negatively impact society, especially its vulnerable members.

39-210 Experiential Learning I

Fall and Spring
The engineer of the 21st century will need to operate effectively in many settings and often with a global perspective. Being curious and constantly looking for inspiration are critical for lifelong learning. This course, designed for all CIT sophomores, requires the student to choose and experience activities for development and growth that are not part of formal course work. Acceptable experiences are listed in the course syllabus on Canvas.

39-220 Experiential Learning II

Fall and Spring
The engineer of the 21st century will need to operate effectively in many settings and often with a global perspective. Being curious and constantly looking for inspiration are critical for lifelong learning. This course, designed for all CIT sophomores, requires the student to choose and experience activities for development and growth that are not part of formal course work. Acceptable experiences are listed in the course syllabus on Canvas.
Prerequisite: 39-210

39-245 Rapid Prototype Design

All Semesters: 9 units
This course provides an introduction to rapid design through virtual and physical prototyping. The class covers the engineering design process, problem solving methods, interdisciplinary team work, current industrial practice, and manufacturing process capabilities. The course emphasizes hands on learning. Sophomores have priority while registering for this course. Juniors and seniors will be put on the waitlist, then released once sophomores have registered.

39-250 CIT Undergraduate Projects

Fall
This course number is to be used for Fall CIT freshman research projects only. Student must complete a CIT Undergraduate Project Approval form (located in Scaife Hall 110) and submit for approval. The form must include a complete description and a signature approval from the research advisor/instructor. If the project is approved, the CIT Undergraduate Studies Office will add the course to the student's fall schedule.

39-251 CIT Undergraduate Projects

Spring
This course number is to be used for Spring CIT freshman research projects only. Student must complete a CIT Undergraduate Project Approval form (located in Scaife Hall 110) and submit for approval. The form must include a complete description and a signature approval from the research advisor/instructor. If the project is approved, the CIT Undergraduate Studies Office will add the course to the student's fall schedule.

39-310 Experiential Learning III

Fall and Spring
The engineer of the 21st century will need to operate effectively in many settings and often with a global perspective. Being curious and constantly looking for inspiration are critical for lifelong learning. This course, designed for all CIT juniors, requires the student to choose and experience activities for development and growth that are not part of formal course work. Acceptable experiences are listed in the course syllabus on Canvas.
Prerequisite: 39-220

39-402 Leadership Development Seminar

All Semesters: 9 units
This course is designed for CIT seniors and juniors committed to further developing their leadership skills and potential for sustained impact in the future. The course will be substantive and engaging, while less technically challenging, outright, than thought provoking, edifying, and enjoyable, ideally. The course will build on the foundation of six key leadership pillars, identified by CIT to hone a student's professional and personal development to serve others, and to seek out and nurture opportunities to heighten one's capacity as a person and leader who is: VISIONARY, with clear goals for yourself, your organizations and communities, and others in whose lives you are a part, including the broader society; ETHICAL, with core values and steadfastness in the face of competing objectives, and the resilience to deal with conflicts without moral compromise; ENGAGING, with empathy, attentive interpersonal attributes, outstanding formal and informal communication skills, and the capacity to inspire; TACTICAL, with an ability to operationalize big ideas and bring them to fruition, creating the ideal environment for individual and group success; TECHNICAL, based on your own high-level skill set and the ego strength for inclusion of others with complementary realms of expertise; REFLECTIVE, manifesting in the honest appraisal of personal and organizational success against metrics, and the ability to redirect based on assessment.

39-447 CIT Undergraduate Interdisciplinary Design Project

All Semesters
This course is to be used for undergraduate research projects involving a significant interdisciplinary design component. It can be added by permission only through collaboration with the student, project advisor, and the CIT Dean's Office. For projects that are not interdisciplinary in nature, students should refer to the research number specific to the department in which the research is being completed.

39-500 CIT Honors Research Project

All Semesters
Juniors who have an accumulated QPA of at least 3.5 receive an invitation to participate in the program. This course, open by invitation only, will provide the opportunity for close interaction with a faculty member through independent honors research in a number of disciplinary and interdisciplinary areas, as part of the CIT Honors Research Program. Students will work on their projects during their senior year, earning the equivalent of 18-24 units. Students are required to register for CIT Honor Research Project 39-500. To receive CIT College Honors, a student must complete at least 18 units in 39-500 on the same research topic and submit a 1-page executive summary of your research. Lastly, students must present their research findings at the Undergraduate Research Symposium, "Meeting of the Minds" in May. Although "Meeting of the Minds" is open to any undergraduate research initiatives occurring on campus, it is a requirement for College of Engineering Honors Research students.

Course Website: https://tinyurl.com/cithonorsresearch (https://tinyurl.com/cithonorsresearch/)

39-601 Special Topics: Additive Manufacturing Processing and Product Development

Fall: 12 units
Introduction to additive manufacturing (AM) processing fundamentals and applications using Solidworks 3-D CAD software and a variety of polymer and metal AM machines. Includes a brief history of AM processing, a review of and technical fundamentals of current AM processes, a study of the current AM market, and future directions of the technology. Lab Sessions will support an open-ended product development project. Lectures on metals AM will address current research impacting industry. Students will also perform a literature review of papers on the state of the art. Basic Solidworks knowledge required.

39-602 Additive Manufacturing and Materials

Fall and Spring: 12 units
This course will develop the understanding required for materials science and engineering for additive manufacturing. The emphasis will be on powder bed machines for printing metal parts, reflecting the research emphasis at CMU. The full scope of methods in use, however, will also be covered. The topics are intended to enable students to understand which materials are feasible for 3D printing. Accordingly, high power density welding methods such as electron beam and laser welding will be discussed, along with the characteristic defects. Since metal powders are a key input, powder-making methods will be discussed. Components once printed must satisfy various property requirements hence microstructure-property relationships will be discussed because the microstructures that emerge from the inherently high cooling rates differ strongly from conventional materials. Defect structures are important to performance and therefore inspection. Porosity is a particularly important feature of 3D printed metals and its occurrence depends strongly on the input materials and on the processing conditions. The impact of data science on this area offers many possibilities such as the automatic recognition of materials origin and history. Finally the context for the course will be discussed, i.e. the rapidly growing penetration of the technology and its anticipated impact on manufacturing.

39-603 Additive Manufacturing Laboratory

Spring: 12 units
Hands-on laboratory projects will teach students about all aspects of metals additive manufacturing (AM). Students will learn how to use SOLIDWORKS for part design, create and transfer design files to the AM machines, run the machines to build parts, perform post-processing operations, and characterize AM parts. Student will work in teams and complete three separate lab projects, each utilizing a different material system, part design, AM process/machine, post-processing steps and characterization methods. A major lab report and presentation will be required for each of the three lab projects. The course includes weekly lectures to complement the laboratory component. Priority for enrollment will be given to students who have declared the Additive Manufacturing Minor.
Prerequisites: 39-602 or 27-503 or 27-765 or 39-601 or 24-632

39-605 Engineering Design Projects

Fall: 12 units
In this project course, students work in multidisciplinary teams to design products or processes. The course is open to juniors, seniors and graduate students from all parts of the campus community. Each project is sponsored by an industry, government or non-profit partner, and is of real commercial interest to that partner. Students work directly with their partner throughout the semester to establish goals and requirements, evaluate their design as it progresses, and produce a final report, presentation, and, if appropriate, a prototype. Design reviews, held twice during the semester, give students a chance to present their preliminary designs and receive feedback and advice. In completing their designs, teams must consider not only the functionality of their designs, but also the look, feel, appearance, and societal impact. Skills built in this course will include: developing the product statement, establishing goals and constraints for the product, project management, and generating and evaluating design alternatives. As some projects may span multiple semesters with new groups of students, careful documentation of project work is emphasized. Students may take this course for either one or two semesters.

39-606 Engineering Design Projects

Spring: 12 units
In this project course, students work in multidisciplinary teams to design products or processes. The course is open to juniors, seniors and graduate students from all parts of the campus community. Each project is sponsored by an industry, government or non-profit partner, and is of real commercial interest to that partner. Students work directly with their partner throughout the semester to establish goals and requirements, evaluate their design as it progresses, and produce a final report, presentation, and, if appropriate, a prototype. Design reviews, held twice during the semester, give students a chance to present their preliminary designs and receive feedback and advice. In completing their designs, teams must consider not only the functionality of their designs, but also the look, feel, appearance, and societal impact. Skills built in this course will include: developing the product statement, establishing goals and constraints for the product, project management, and generating and evaluating design alternatives. As some projects may span multiple semesters with new groups of students, careful documentation of project work is emphasized. Students may take this course for either one or two semesters.

39-647 Special Topics in Design

All Semesters
This course is to be use for Interdisciplinary Engineering Design Independent Study. It can be added by permission only through collaboration with the student, Independent Study project advisor, and the CIT Dean's Office.

39-648 Rapid Prototyping of Computer Systems

Spring: 12 units
This course deals with rapid prototyping, manufacture, and applications of a new generation of wearable computers, with head-mounted display. The design of wearable computers is a multidisciplinary process including: Electronic design, mechanical design, software development, and human-computer interaction. Two classes of wearable computers will be further developed: embedded, custom designed VuMan series, and general purpose Navigator series. Electronic design includes the custom designed computer board, electronic interfacing, and power supply. Industrial designers and mechanical engineers team to design and manufacture with in-house facilities a variety of conformable/lightweight housings. A software development environment and user interface builders support software and application development. Current applications include: Global Position Sensing, Hypertext documents, speech recognition, wireless communications, and digital imaging.

Department of Biomedical Engineering

Keith E. Cook, Department Head and The David Edward Schramm Professor

Jana Kainerstorfer, Associate Department Head for Faculty and Graduate Affairs

Location: Scott Hall 4N201
www.cmu.edu/bme (http://www.cmu.edu/bme/)

Biomedical Engineering Overview

Biomedical Engineering education at Carnegie Mellon University reflects the belief that a top biomedical engineer must be deeply trained in both a traditional engineering practice and biomedical sciences. The unique additional major in Biomedical Engineering program leverages extensive collaborations with sister departments in the College of Engineering and with major medical institutions in Pittsburgh. This collaborative approach, combined with a rigorous engineering education, confers unique depth and breadth to the education of Biomedical Engineering graduates. The Biomedical Engineering department also offers an additional major in Biomedical Technology, which is open to all non-engineering students who want training beyond the Biomedical Engineering minor. The additional major curricula, demanding but readily feasible to complete in four years, are highly rewarding to motivated students.

Additional Major in Biomedical Engineering (BME) for Engineering Majors

Students who elect Biomedical Engineering as a major ***must also declare a major in one of the traditional engineering disciplines.*** The Biomedical Engineering additional major program takes advantage of curricular overlaps between Biomedical Engineering and primary Engineering majors, such that the additional major can be completed in four years with only a modest increase in course requirements. The requirements for Biomedical Engineering additional major program consist of the core, the tracks, and the capstone design course. The core exposes students to basic facets of biomedical engineering to lay a foundation. The tracks allow students to build depth in a specific aspect of biomedical engineering. The capstone design (https://www.cmu.edu/bme/Academics/undergraduate-programs/Resources/undergrad_design.html) project engages students in teamwork to develop real-world devices and technologies. *The additional major in Biomedical Engineering should be declared at the same time when declaring a traditional engineering major.*

Additional Major in Biomedical Technology (BMT) for Non-engineering Majors

The Biomedical Technology major is ***open to all non-engineering students***. Biomedical Technology is for students from non-engineering majors who want Biomedical Engineering training beyond the BME minor. The requirements for the Biomedical Technology additional major program consist of the core, the tracks, and the capstone design course. The core exposes students to basic facets of biomedical engineering to lay a foundation. The tracks allow students to build depth in a specific aspect of biomedical engineering. The capstone design (https://www.cmu.edu/bme/Academics/undergraduate-programs/Resources/undergrad_design.html) project engages students in teamwork to develop real-world applications. *The additional major in Biomedical Technology should be declared at the same time when declaring a primary major or by the second semester of the first year.*

Minor in Biomedical Engineering

The minor program is designed for students who desire exposure to biomedical engineering but may not have the time to pursue the Biomedical Engineering additional major. The program is ***open to students of all colleges*** and is popular among both engineering and science majors. In conjunction with other relevant courses, the program may provide a sufficient background for jobs or graduate studies in biomedical engineering. Students interested in a medical career may also find this program helpful.

Additional Major in Biomedical Engineering (BME) for Engineering Majors

PROGRAM REQUIREMENTS

Students who elect Biomedical Engineering (BME) as a major ***must also declare a major in one of the traditional engineering disciplines:*** Chemical Engineering, Civil Engineering, Electrical & Computer Engineering, Environmental Engineering, Materials Science & Engineering, or Mechanical Engineering. Students majoring in Biomedical Engineering must meet **three** sets of requirements: 1) Biomedical Engineering, 2) Primary Major, and 3) General Education. The Quality Point Average (QPA) for courses that count toward the additional major must be 2.00 or better. No course taken on a pass/fail or audit basis may be counted towards the additional major. *The additional major should be declared at the same time when declaring a primary major or by the second semester of the first year.*

Minimum units required for additional major (Core Courses + Track Electives): 93 - 102

Core Courses

All core courses are required.

		Units
03-121	Modern Biology	9
or 03-151	Honors Modern Biology	
42-101	Introduction to Biomedical Engineering	12
42-201	Professional Issues in Biomedical Engineering	3
42-202	Physiology	9
42-203	Biomedical Engineering Laboratory #	9
42-302	Biomedical Engineering Systems Modeling and Analysis	9
42-401	Foundation of BME Design *	6
42-402	BME Design Project	9
Total units of Core Courses		**66**

Also known as 03-206 for Health Professions Program (http://www.cmu.edu/hpp/) students.
* 42-401 serves as the precursor/pre-requisite for 42-402 BME Design Project.

Track Electives

Completion of ***one track*** is required. See **Tracks for BME/BMT Major** for Track Elective lists.

		Units
42-XXX	Required Elective from the selected track	9 - 12
XX-XXX	Required or Additional Elective from the selected track	9 - 12
XX-XXX	Required or Additional Elective from the selected track	9 - 12
Total units of Track Electives		**27-36**

Additional Major in Biomedical Technology (BMT) for Non-Engineering Majors

PROGRAM REQUIREMENTS

The Biomedical Technology (BMT) major is ***open to all non-engineering students***. The Biomedical Technology is for students from non-engineering majors who want Biomedical Engineering training beyond the BME minor. Students majoring in Biomedical Technology must meet **three** sets of requirements: 1) Biomedical Technology, 2) Primary Major, and 3) General Education. The Quality Point Average (QPA) for courses that count toward the additional major must be 2.00 or better. No course taken on a pass/fail or audit basis may be counted towards the additional major. *The additional major should be declared at the same time when declaring a primary major or by the second semester of the first year.*

Minimum units required for additional major (Core Courses + Track Electives): 84 - 93

Core Courses

All core courses are required.

		Units
03-121	Modern Biology	9
or 03-151	Honors Modern Biology	
42-101	Introduction to Biomedical Engineering	12
42-201	Professional Issues in Biomedical Engineering	3
42-202	Physiology	9
42-203	Biomedical Engineering Laboratory #	9
42-401	Foundation of BME Design *	6
42-402	BME Design Project	9
Total units of Core Courses		**57**

Also known as 03-206 for Health Professions Program (http://www.cmu.edu/hpp/) students.
* 42-401 serves as the precursor/pre-requisite for 42-402 BME Design Project.

Track Electives

Completion of ***one track*** is required. See **Tracks for BME/BMT Major** for Track Elective lists.

		Units
42-XXX	Required Elective from the selected track	9 - 12
XX-XXX	Required or Additional Elective from the selected track	9 - 12
XX-XXX	Required or Additional Elective from the selected track	9 - 12
Total units of Track Electives		**27-36**

Minor in Biomedical Engineering

Kristin Kropf, *Undergraduate Program and Alumni Relations Coordinator, Biomedical Engineering*
Email: kgaluska@andrew.cmu.edu
https://www.cmu.edu/bme/Academics/undergraduate-programs/minor.html

The minor program is designed for students who desire exposure to biomedical engineering but may not have the time to pursue the Biomedical Engineering additional major. The program is open to students of **all** colleges and is popular among both engineering and science majors. In conjunction with other relevant courses, the program may provide a sufficient background for jobs or graduate studies in biomedical engineering. Students interested in a medical career may also find this program helpful.

The Biomedical Engineering minor curriculum is comprised of three core courses and three electives. The Quality Point Average (QPA) for courses that count toward the minor must be 2.00 or better. No course taken on a pass/fail or audit basis may be counted towards the minor.

Students who have questions or are interested in declaring Biomedical Engineering minor should contact Kristin Kropf (kgaluska@andrew.cmu.edu).

PROGRAM REQUIREMENTS

Minimum units required for minor: 57

03-121	Modern Biology	9
or 03-151	Honors Modern Biology	
42-101	Introduction to Biomedical Engineering	12
42-202	Physiology	9
42-xxx	BME Elective I	9-12
42-xxx	BME Elective II	9-12
42-xxx	BME Elective III	9-12

A BME Elective is defined as one of the following:

1. One semester of 42-200 Sophomore BME Research Project, 42-300 Junior BME Research Project, 42-400 Senior BME Research Project or 39-500 Honors Research Project. The project must be supervised by a core or courtesy Biomedical Engineering faculty member and for 9 or more units. Research projects supervised by a courtesy Biomedical Engineering faculty member must have significant biomedical engineering relevance. Note that BME Research Project can only be count as one BME elective.
2. 42-203 BME Laboratory (or the cross-listed version 03-206 for students in the Health Professions Program). Please note that priority for enrollment in 42-203 or 03-206 will be given to students who have declared the Additional Major in Biomedical Engineering. If sufficient room in the course remains after all majors have been accommodated in a given semester, students who have declared the Biomedical Engineering Designated Minor will be given the next priority for enrollment. If space still allows, other students will be enrolled.
3. Any 42-xxx course with a course number greater than 42-300 and worth at least 9 units (excluding 42-300 and 42-400- see previous comment regarding BME Research Project).

Note that non-BME, track elective courses for BME major do not automatically qualify as BME minor electives. Students can petition the Biomedical Engineering Undergraduate Affairs Committee to count non-BME classes that have significant biological/medical *and* engineering contents towards the minor requirements. The course petition form can be found here (https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition).

Biomedical Engineering/Technology Tracks

Completion of one track is required. † Denotes tracks that are not offered to Classes of 2027+.

- Biomechanics (BMEC (p. 91))
- Biomedical Devices (BMDV (p. 92))
- Biomedical Signal and Image Processing (BSIP (p. 92))
- Neuroengineering (Neuro (p. 93))
- Tissue and Cell Biotherapeutics (TCB (p. 93))
- Biomaterials and Tissue Engineering (BMTE (p. 94)) †
- Cellular and Molecular Biotechnology (CMBT (p. 94)) †
- Self-Designed Biomedical Engineering (SBME (p. 94))

Biomechanics (BMEC) Track

OVERVIEW

The BMEC track addresses the application of solid or fluid mechanics to biological and medical systems. It provides quantitative understanding of the mechanical behavior of molecules, cells, tissues, organs, and whole organisms. The field has seen a wide range of applications from the optimization of tissue regeneration to the design of surgical and rehabilitation devices.

TARGETS

The BMEC track is ideally suited to the combined education of Biomedical Engineering and Mechanical Engineering or Civil & Environmental Engineering. Both provide the necessary foundation in the underlying physical principles and their non-Biomedical Engineering applications. This track may also appeal to students of Electrical & Computer Engineering who are interested in biomedical robotics. Education in biomechanics enables students to pursue careers in medical devices or rehabilitation engineering.

REQUIREMENTS

In addition to the Biomedical Engineering core courses, students in the BMEC Track must take must take the following combination of **three** courses:

- One (1) **Required** BMEC Elective
- Two (2) BMEC Electives (either **Required** or **Additional**)

BMEC ELECTIVES

Required BMEC Electives (must take at least one of the following)

42-649/24-664	Introduction to Biomechanics	12
42-648/	Cardiovascular Mechanics	12
42-645/24-655	Cellular Biomechanics	9
42-691/24-663	Biomechanics of Human Movement	12

Additional BMEC Electives

42-641	Rehabilitation Engineering	9
42-640/24-658	Image-Based Computational Modeling and Analysis	12
42-444	Medical Devices	9
42-696/24-665	Special Topics: Wearable Health Technologies	12
16-868	Biomechanics & Motor Control	12
16-879	Medical Robotics	12
42-x00	BME Research* or 39-500 CIT Honors Research Project* or 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine)	9-12

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 CIT Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics and newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their BME advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as track electives. The course petition form can be found here (https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition).

Sample schedules can be found on the BME Additional Major (https://www.cmu.edu/bme/Academics/undergraduate-programs/major.html) page on the BME website.

Biomedical Devices (BMDV) Track

OVERVIEW

The BMDV track studies design, construction, and testing of devices at the interface of medicine and engineering. The topics include biomedical sensors, actuators, diagnostic devices, therapeutic devices, instruments, systems, and fundamental topics of device material, device fabrication, and device interaction with biological cells, tissues and organs. The Biomedical Device track will prepare students for leaders in the biomedical device industry and for further education in graduate/medical schools.

TARGETS

The BMDV track will prepare students to be leaders in the biomedical device industry and for further education in graduate/medical schools. It is ideal for students interested in combining the education of Biomedical Engineering with Electrical and Computer Engineering, or with Mechanical Engineering, or with Materials Science & Engineering.

REQUIREMENTS

In addition to the Biomedical Engineering core courses, students in the BMDV Track must take must take the following combination of **three** courses:

- One (1) **Required** BMDV Elective
- Two (2) BMDV Electives (either **Required** or **Additional**)

BMDV ELECTIVES

Required BMDV Electives (must take at least one of the following)

42-660	Bioinstrumentation	12
42-678	Medical Device Innovation and Realization	12
42-693/18-469	Special Topics in Integrated Systems Technology: Micro/Nano Biomedical Devices	12
42-694	Engineering Principles of Medical Devices	9

Additional BMDV Electives

42-433	Neural Technology: Sensing and Stimulation	12
42-444	Medical Devices	9
42-611/27-709	Biomaterials	12
42-616/27-514	Bio-nanotechnology: Principles and Applications	9
42-630	Introduction to Neural Engineering	12
42-641	Rehabilitation Engineering	9
42-648/	Cardiovascular Mechanics	12
42-650	Introduction to Biomedical Imaging	9
42-652/18-416	Nano-Bio-Photonics	12
42-675	Fundamentals of Computational Biomedical Engineering	12
42-696/24-665	Special Topics: Wearable Health Technologies	12
16-467	Introduction to Human Robot Interaction	12
16-879	Medical Robotics	12
42-6XX	Clinical Course (Surgery for Engineers/ Precision Medicine/ICU Medicine)	9
42-X00	BME Research* or 39-500 CIT Honors Thesis	9

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 CIT Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics and newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their BME advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as track electives. The course petition form can be found here (https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition).

Sample schedules can be found on the BME Additional Major (https://www.cmu.edu/bme/Academics/undergraduate-programs/major.html) page on the BME website.

Biomedical Signal and Image Processing (BSIP) Track

OVERVIEW

The BSIP track addresses biomedical phenomena based on the information embedded in sensor-detected signals, including digital images and nerve electrical pulses. Students in this track will gain an understanding of the technologies involved in acquiring signals and images, the mathematical principles underlying the processing and analysis of signals, and the applications of signal/image processing methods in basic research and medicine.

TARGETS

This track aligns most naturally with a combined education of Biomedical Engineering and Electrical & Computer Engineering, which lays a solid foundation in signal processing principles. This track prepares students for careers in medical imaging or smart prosthetics. It also interfaces with many clinical practices including radiology, neurology/neurosurgery, and pathology.

REQUIREMENTS

In addition to the Biomedical Engineering core courses, students in the BSIP Track must take the following combination of **three** courses:

- One (1) **Required** BSIP elective
- Two (2) BSIP Electives (either **Required** or **Additional**)

BSIP ELECTIVES

Required BSIP Electives (must take at least one of the following)

42-650	Introduction to Biomedical Imaging	9
42-668	"Fun"-damentals of MRI and Neuroimaging Analysis	9
42-631	Neural Data Analysis	12
42-632	Neural Signal Processing	12

Additional BSIP Electives

42-437	Biomedical Optical Imaging	9
42-640/24-658	Image-Based Computational Modeling and Analysis	12
42-656	Introduction to Machine Learning for Biomedical Engineers	9
42-660	Bioinstrumentation	12
42-675	Fundamentals of Computational Biomedical Engineering	12
16-725	(Bio)Medical Image Analysis	12

18-491	Digital Signal Processing [1]	12
42-x00	BME Research* or 39-500 CIT Honors Research Project* or 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine)	9-12

[1] Students make take either 18-491 Fundamentals of Signal Processing OR 18-792 Advanced Digital Signal Processing (but not both)

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 CIT Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics and newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their BME advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as track electives. The course petition form can be found here (https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition).

Sample schedules can be found on the BME Additional Major (https://www.cmu.edu/bme/Academics/undergraduate-programs/major.html) page on the BME website.

Neuroengineering (Neuro) Track

OVERVIEW

The Neuroengineering (Neuro) track uses engineering techniques to examine, understand, and apply the properties of complex neural systems. Areas of interest include the research and development of neuroengineering technologies for sensing, interfacing, imaging, and modulating the nervous systems. Examples of applications include brain-computer interfaces for use in paralysis, neural stimulation device design for sensory and motor prostheses and basic science research, and neural recording and imaging devices.

TARGETS

This track aligns most naturally with a combined education of Biomedical Engineering and Electrical & Computer Engineering, which lays a solid foundation in signal processing principles. This track prepares students for careers in brain-computer interfaces, neural stimulators, and neuroprosthetics.

REQUIREMENTS

In addition to the Biomedical Engineering core courses, students in the BMEC Track must take must take the following combination of **three** courses:

- One (1) **Required** Neuro Elective
- Two (2) Neuro Electives (either **Required** or **Additional**)

NEURO ELECTIVES

Required Neuro Electives (must take at least one of the following)

42-630	Introduction to Neural Engineering	12
42-631	Neural Data Analysis	12
42-632	Neural Signal Processing	12

Additional Neuro Electives

42-433	Neural Technology: Sensing and Stimulation	12
42-437	Biomedical Optical Imaging	9
42-641	Rehabilitation Engineering	9
42-650	Introduction to Biomedical Imaging	9
42-652/18-416	Nano-Bio-Photonics	12
42-656	Introduction to Machine Learning for Biomedical Engineers	9
42-660	Bioinstrumentation	12
42-783	Neural Engineering Laboratory	12
15-386	Neural Computation	9
18-370	Fundamentals of Control	12
18-460	Optimization	12

42-x00	BME Research* or 39-500 CIT Honors Research Project* or 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine)	9-12

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 CIT Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics and newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their BME advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as track electives. The course petition form can be found here (https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition).

Sample schedules can be found on the BME Additional Major (https://www.cmu.edu/bme/Academics/undergraduate-programs/major.html) page on the BME website.

Tissue and Cell Biotherapeutics (TCB) Track

Note: This track combines the Biomaterials and Tissue Engineering (BMTE) and Cellular and Molecular Biotechnology (CMBT) tracks together. Students entered CMU prior to Fall 2024 may switch to this track.

OVERVIEW

The TCB track addresses issues at the interface of materials science, biology and engineering. The topics include the interactions between materials and cells or tissues, the effects of such interactions on cells and tissues, the design of materials for biological applications, and the engineering of new tissues. It emphasizes fundamentals and applications of biochemistry, biophysics, cell biology, material science, and processes on the nanometer to centimeter size scale. Students in this track acquire an understanding of the molecular and cellular bases of life processes and build skills in quantitative modeling of biological mass transport, drug delivery, and live cell-based biotechnologies and in technologies that exploit the unique properties of biomolecules and materials in non-biological settings.

TARGETS

The TCB track is ideal for students interested in combining the education of Biomedical Engineering with Materials Science & Engineering or with Chemical Engineering. The track may also interest students in Mechanical Engineering and Environmental Engineering who have an interest in molecular aspects of Biomedical Engineering. It provides the necessary foundation in chemistry, molecular processing, and/or materials science. Students of this track may develop careers in biotechnology, tissue engineering, biopharmaceuticals, biosensors, drug delivery, and biological aspects of environmental engineering.

REQUIREMENTS

In addition to the Biomedical Engineering core courses, students in the TCB Track must take the following combination of **three** courses:

- One (1) **Required** TCB elective
- Two (2) TCB Electives (either **Required** or **Additional**)

TCB ELECTIVES

Required TCB Electives (must take one of the following)

42-611/27-709	Biomaterials	12
42-612/27-520	Tissue Engineering	12
42-615	Biomaterial Host Interactions in Regenerative Medicine	12
42-620	Engineering Molecular Cell Biology	12
42-624	Biological Transport and Drug Delivery	9

Additional TCB Electives

42-613/27-570	Polymeric Biomaterials	12
42-616/27-514	Bio-nanotechnology: Principles and Applications	9
42-626/06-634	Drug Delivery Systems	9
42-645/24-655	Cellular Biomechanics	9
42-667	Biofabrication and Bioprinting	12
42-695	Special Topics: Engineering Protein Therapeutics	12
42/06-722	Bioprocess Design	12
03-320	Cell Biology	9

06-685	Bioseparations and Bioprocess Analytical Technologies	12
42-x00	BME Research* or 39-500 CIT Honors Research Project* or 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine)	9-12

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 CIT Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics and newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their BME advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as track electives. The course petition form can be found here (https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition).

Biomaterials and Tissue Engineering (BMTE) Track

Note: This track is not offered to Classes of 2027+

OVERVIEW

The BMTE track addresses issues at the interface of materials science, biology and engineering. The topics include the interactions between materials and cells or tissues, the effects of such interactions on cells and tissues, the design of materials for biological applications, and the engineering of new tissues.

TARGETS

The BMTE track is ideal for students interested in combining the education of Biomedical Engineering with Materials Science & Engineering or with Chemical Engineering. Both provide the necessary foundation in chemistry and/or materials science. Students of this track may develop careers in biotechnology, tissue engineering, biopharmaceuticals, and medical devices that leverage materials properties.

REQUIREMENTS

In addition to the Biomedical Engineering core courses, students in the BMTE Track must take the following combination of **three** courses:

- One (1) **Required** BMTE elective
- Two (2) BMTE Electives (either **Required** or **Additional**)

BMTE ELECTIVES

Required BMTE Electives (must take one of the following)

42-611/27-709	Biomaterials	12
42-612/27-520	Tissue Engineering	12
42-615	Biomaterial Host Interactions in Regenerative Medicine	12
42-667	Biofabrication and Bioprinting	12

Additional BMTE Electives

42-613/27-570	Polymeric Biomaterials	12
42-616/27-514	Bio-nanotechnology: Principles and Applications	9
42-620	Engineering Molecular Cell Biology	12
42-624	Biological Transport and Drug Delivery	9
03-320	Cell Biology	9
42-x00	BME Research* or 39-500 CIT Honors Research Project* or 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine)	9-12

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 CIT Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics and newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their BME advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as track electives. The course petition form can be found here (https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition).

Sample schedules can be found on the BME Additional Major (https://www.cmu.edu/bme/Academics/undergraduate-programs/major.html) page on the BME website.

Cellular and Molecular Biotechnology (CMBT) Track

Note: This track is not offered to Classes of 2027+

OVERVIEW

The CMBT track emphasizes fundamentals and applications of biochemistry, biophysics, and cell biology, and processes on the nanometer to micrometer size scale. Students in this track acquire understanding of the molecular and cellular bases of life processes, and build skills in quantitative modeling of biological mass transport, drug delivery, and live cell-based biotechnologies and in technologies that exploit the unique properties of biomolecules in non-biological settings.

TARGETS

The CMBT track is ideally suited for the combined education of Biomedical Engineering and Chemical Engineering, which provides a strong core of chemistry and molecular processing principles. The track may also interest students of Mechanical Engineering, Materials Science & Engineering, or Civil & Environmental Engineering who have an interest in molecular aspects of Biomedical Engineering. The CMBT track prepares students for careers in bio/pharmaceutical, medical diagnostics, biosensors, drug delivery, and biological aspects of environmental engineering.

REQUIREMENTS

In addition to the Biomedical Engineering core courses, students in the CMBT Track must take the following combination of **three** courses:

- One (1) **Required** CMBT Elective
- Two (2) CMBT Electives (either **Required** or **Additional**)

CMBT ELECTIVES

Required CMBT Electives (must take at least one of the following)

42-620	Engineering Molecular Cell Biology	12
42-621	Principles of Immunoengineering and Development of Immunotherapy Drugs	9
42-624	Biological Transport and Drug Delivery	9

Additional CMBT Electives

42-616/27-514	Bio-nanotechnology: Principles and Applications	9
42-626/06-634	Drug Delivery Systems	9
42-645/24-655	Cellular Biomechanics	9
42/06-722	Bioprocess Design	12
03-320	Cell Biology	9
42-x00	BME Research* or 39-500 CIT Honors Research Project* or 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine)	9-12

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 CIT Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics and newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their BME advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as track electives. The course petition form can be found here (https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition).

Sample schedules can be found on the BME Additional Major (https://www.cmu.edu/bme/Academics/undergraduate-programs/major.html) page on the BME website.

Self-Designed Biomedical Engineering (SBME) Track

The SBME track is aimed at helping highly motivated students who have a strong sense of career direction that falls beyond the scope of regular Biomedical Engineering tracks. Students are allowed to design the "track" portion of the curriculum in consultation with the faculty. Example themes include medical robotics, embedded medical systems, or computational biomedical engineering.

REQUIREMENTS

In addition to the Biomedical Engineering core requirements, students must take **three** elective courses of at least 9 units each. These elective courses must form a coherent theme that is relevant to biomedical engineering. In addition, at least one of the elective courses must be judged by the Biomedical Engineering Undergraduate Affairs Committee to have substantial biological or medical content.

If undergraduate research is part of the SBME track, the research project must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

PETITION PROCEDURE

1. Students wishing to pursue a self-designed track should first consult with Kristin Kropf (https://engineering.cmu.edu/directory/bios/kropf-kristin.html) (Undergraduate Program and Alumni Relations Coordinator).
2. A SBME track proposal must be submitted electronically to Kristin Kropf (https://engineering.cmu.edu/directory/bios/kropf-kristin.html) at least three weeks prior to Pre-Registration during the spring of the sophomore year. The proposal must include:
   - The three courses of the designed track, including catalog descriptions and when these courses are expected to be taken.
   - A justification of how these courses form a coherent theme relevant to biomedical engineering and why the regular tracks do not relate to the proposed theme
   - Two alternative courses that may substitute for one of the proposed courses, in case the original course is not available.
3. Once approved by the Biomedical Engineering Undergraduate Affairs Committee, the student must sign an agreement listing the theme and the three courses comprising the SBME track.
4. In the event that issues beyond the student's control, such as course scheduling or cancellation, prevent the student from completing the approved course plan, the student may petition the Biomedical Engineering Undergraduate Affairs Committee to
5. Substitute a course with another course that fits the approved theme, OR
6. Complete one of the regular tracks (all classes)

Full-Time Faculty

ABBOTT, ROSALYN, Associate Professor of Biomedical Engineering – Ph.D., University of Vermont, 2011;

BARATI FARIMANI, AMIR, Assistant Professor, Mechanical Engineering and Biomedical Engineering – Ph.D., University of Illinois at Urbana-Champaign, 2015;

BARTH, ALISON L., Professor, Biological Sciences, and Biomedical Engineering – Ph.D., University of California, Berkeley, 1997;

BETTINGER, CHRISTOPHER J. , Professor of Biomedical Engineering and Materials Science & Engineering – Ph.D., Massachusetts Institute of Technology, 2008;

CAMPBELL, PHIL G. , Research Professor, Biomedical Engineering, Engineering Research Accelerator, Biological Sciences, and Materials Science & Engineering – Ph.D., The Pennsylvania State University, 1985;

CHALACHEVA, P. SANG, Assistant Teaching Professor of Biomedical Engineering – Ph.D., University of Southern California, 2014;

CHAMANZAR, MAYSAM , Dr. William D. and Nancy W. Strecker Career Development Associate Professor, Electrical and Computer Engineering, Biomedical Engineering – Ph.D., Georgia Institute of Technology, 2012;

CHASE, STEVEN M., Professor of Biomedical Engineering and Center for the Neural Basis of Cognition – Ph.D., Johns Hopkins University, 2006;

CHOSET, HOWIE, Professor, Robotics Institute, Biomedical Engineering, and Electrical & Computer Engineering – Ph.D., California Institute of Technology , 1996;

COHEN-KARNI, TZAHI (ITZHAQ), Professor of Biomedical Engineering and Materials Science & Engineering – Ph.D., Harvard University, 2011;

COOK, KEITH E., David Edward Schramm Professor and Department Head, Biomedical Engineering – Ph.D., Northwestern University, 2000;

DANDIN, MARC, Assistant Professor, Electrical & Computer Engineering and Biomedical Engineering – Ph.D., University of Maryland, 2012;

DOMACH, MICHAEL M., Professor, Chemical Engineering and Biomedical Engineering – Ph.D., Cornell University, 1983;

ERICKSON, ZACKORY, Assistant Professor, Robotics Institute and Biomedical Engineering – Ph.D., Georgia Institute of Technology, 2021;

FEDDER, GARY K., Howard M. Wilkoff Professor, Institute for Complex Engineering Systems, Biomedical Engineering, Electrical & Computer Engineering, Robotics Institute – Ph.D., University of California, Berkeley, 1994;

FEINBERG, ADAM W., Arthur Hamerschlag Career Development Professor; Professor of Biomedical Engineering and Materials Science & Engineering – Ph.D., University of Florida, 2004;

GALEOTTI, JOHN, Senior Systems Scientist, Robotics Institute and Associate Professor of Biomedical Engineering – Ph.D, Carnegie Mellon University, 2007;

GEYER, HARMUT, Associate Professor, Robotics Institute and Biomedical Engineering – Ph.D., Friedrich-Schiller-University of Jena, Germany, 2005 ;

GITTIS, ARYN, Associate Professor, Biological Sciences, and Biomedical Engineering – Ph.D., University of California, San Diego, 2008;

GRANDE GUTIÉRREZ, NOELIA, Assistant Professor, Mechanical and Biomedical Engineering – PhD, Stanford, 2019;

GROVER, PULKIT, Angel Jordan Associate Professor, Electrical & Computer Engineering, Center for Neural Basis of Cognition, and Biomedical Engineering – Ph.D., University of California, Berkeley, 2010;

HALILAJ, ENI, Assistant Professor, Mechanical Engineering and Biomedical Engineering – Ph.D., Brown University, 2015;

HAMMAL, ZAKIA, Systems Faculty, Robotics Institute; Assistant Research Professor, Biomedical Engineering – Ph.D.,

HE, BIN, Trustee Professor of Biomedical Engineering, Electrical & Computer Engineering, Neuroscience Institute – Ph.D., Tokyo Institute of Technology, 1988;

JUST, MARCEL, D.O. Hebb University Professor of Psychology and Biomedical Engineering Director, Center for Cognitive Brain Imaging – Ph.D., Stanford University, 1972;

KAINERSTORFER, JANA M., Professor and Associate Department Head for Faculty and Graduate Affairs, Biomedical Engineering – Ph.D., University of Vienna, 2010;

KASS, ROBERT, Maurice Falk Professor, Statistics, Department of Machine Learning, Center for the Neural Basis of Cognition, and Biomedical Engineering Interim co-Director, Center for the Neural Basis of Cognition – Ph.D., University of Chicago, 1980;

KELLY, SHAWN, Adjunct Associate Professor of Biomedical Engineering – Ph.D., Massachusetts Institute of Technology, 2003;

KUHLMAN, SANDRA, Associate Professor, Biological Sciences, and Biomedical Engineering – Ph.D., University of Kentucky, 2001;

LEDUC, PHILIP R., William J. Brown Professor of Mechanical Engineering, Biomedical Engineering, and Biological Sciences – Ph.D., Johns Hopkins University, 1999;

LEE, TAI SING, Professor, Computer Science, Center for the Neural Basis of Cognition and Biomedical Engineering – Ph.D., Harvard University, 1993;

MAJIDI, CARMEL, Associate Professor of Mechanical Engineering and Biomedical Engineering – Ph.D., University of California, Berkeley, 2007;

MOORE, AXEL, Assistant Professor, Biomedical Engineering – Ph.D., University of Delaware, 2017;

NIEPA, TAGBO H.R., Associate Professor, Biomedical Engineering and Chemical Engineering – Ph.D., Syracuse University, 2014;

OLSON, CARL, Professor, Center for the Neural Basis of Cognition and Biomedical Engineering – Ph.D., University of California, Berkeley, 1979;

OZDOGANLAR, BURAK , Ver Planck Professor, Mechanical Engineering and Biomedical Engineering – Ph.D., University of Michigan, 1999;

PALCHESKO, RACHELLE, Assistant Teaching Professor of Biomedical Engineering – Ph.D., Duquesne University, 2011;

PANAT, RAHUL, Russell V. Trader Associate Professor, Mechanical Engineering, Civil & Environmental Engineering, Materials Science & Engineering, and Biomedical Engineering – Ph.D., University of Illinois at Urbana-Champaign, 2004;

REN, XI (CHARLIE), Associate Professor of Biomedical Engineering – Ph.D., Peking University, 2011;

RIVIERE, CAMERON N., Associate Research Professor, Robotics Institute and Biomedical Engineering – Ph.D., Johns Hopkins University, 1995;

SCHNEIDER, JAMES W., Professor of Chemical Engineering and Biomedical Engineering – Ph.D., University of Minnesota, 1998;

SHIMADA, KENJI, Theodore Ahrens Professor, Mechanical Engineering and Biomedical Engineering – Ph.D., Massachusetts Institute of Technology, 1993;

SHINN-CUNNINGHAM, BARBARA, Director, Carnegie Mellon Neuroscience Institute Professor, Center for the Neural Basis of Cognition, Biomedical Engineering, Psychology, and Electrical & Computer Engineering – Ph.D., Massachusetts Institute of Technology, 1994;

SMITH, MATTHEW, Professor, Biomedical Engineering and Center for the Neural Basis of Cognition – Ph.D., New York University, 2003;

SYDLIK, STEFANIE, Professor of Chemistry and Biomedical Engineering – Ph.D., Massachusetts Institute of Technology, 2012;

SZAFRON, JASON, Assistant Professor, Biomedical Engineering – Ph.D., Yale University, 2020;

TAYLOR, REBECCA, Ph.D. – Associate Professor of Mechanical Engineering and Biomedical Engineering, Stanford University, 2013;

TILTON, ROBERT D. , Chevron Professor; Professor, Biomedical Engineering and Chemical Engineering – Ph.D., Stanford University, 1991;

TRUMBLE, DENNIS, Emeritus Research Professor, Biomedical Engineering and Center for the Neural Basis of Cognition – Ph.D., Carnegie Mellon University, 2010;

TUCKER, CONRAD, Director of CMU-Africa and Associate Dean for International Affairs-Africa, Professor of Mechanical Engineering, Biomedical Engineering, Machine Learning, and the Robotics Institute – PhD, MBA, University of Illinois, Urbana-Champaign, 2011;

VERSTYNEN, TIMOTHY, Associate Professor, Psychology, Center for the Neural Basis of Cognition and Biomedical Engineering – Ph.D., University of California, Berkeley, 2006;

WANG, YU-LI, Mehrabian Professor of Biomedical Engineering – Ph.D., Harvard University, 1980;

WASHBURN, NEWELL R. , Associate Professor of Biomedical Engineering, Chemistry, and Materials Science & Engineering – Ph.D., University of California, Berkeley, 1998;

WEBER, DOUGLAS J, Akhtar and Bhutta Professor, Mechanical Engineering, Neuroscience Institute and Biomedical Engineering – Ph.D., Arizona State University, 2001;

WEBSTER-WOOD, VICTORIA , Assistant Professor, Mechanical Engineering and Biomedical Engineering – Ph.D., Case Western Reserve University, 2017;

WHITEHEAD, KATHRYN A, Professor of Chemical and Biomedical Engineering – Ph.D., University of California, Santa Barbara, 2007;

WOOD, SOSSENA, Assistant Professor of Biomedical Engineering – Ph.D., University of Pittsburgh, 2018;

YTTRI, ERIC, Assistant Professor, Biological Sciences, Center for the Nneural Basis of Cognition, Biomedical Engineering – Ph.D., Washington University in St Louis, 2011;

YU, BYRON, Gerard G. Elia Career Development Professor of Biomedical Engineering and Electrical & Computer Engineering – Ph.D., Stanford University, 2007;

YU, KAI, Research Scientist of Biomedical Engineering – Ph.D., University of Minnesota, Minneapolis, 2018;

ZAPANTA, CONRAD M., Associate Dean of Undergraduate Studies, College of Engineering and Teaching Professor, Biomedical Engineering, – Ph.D., The Pennsylvania State University, 1997;

ZHANG, YONGJIE JESSICA, George Tallman Ladd and Florence Barrett Ladd Professor, Mechanical Engineering and Biomedical Engineering – Ph.D., University of Texas at Austin, 2005;

ZHAO, YONGXIN (LEO), Associate Professor, Biomedical Engineering and Biological Sciences – Ph.D., University of Alberta, 2014;

ZHENG, SIYANG, Professor, Biomedical Engineering and Electrical and Computer Engineering – Ph.D., California Institute of Technology, 2007;

Department of Biomedical Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

42-101 Introduction to Biomedical Engineering

Fall and Spring: 12 units
This course will provide exposure to basic biology and engineering problems associated with living systems and health care delivery. Examples will be used to illustrate how basic concepts and tools of science and amp; engineering can be brought to bear in understanding, mimicking and utilizing biological processes. The course will focus on four areas: biotechnology, biomechanics, biomaterials and tissue engineering and biosignal and image processing and will introduce the basic life sciences and engineering concepts associated with these topics.

42-200 Sophomore BME Research Project

Fall and Spring
Research projects for sophomores under the direction of a regular or adjunct BME faculty member. Arrangements may also be made via the Associate Head of BME for off-campus projects provided that a regular or adjunct BME faculty member agrees to serve as a co-advisor. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the research advisor. The agreement should be summarized in a two-page project description with sign-off by the research advisor and a copy submitted for review and filing with the BME Department. A final written report of the results is required. Units may vary from 9 to 12 according to the expected time commitment, with one unit corresponding to 1 hour of research per week. One (but not more than one) semester of research, if registered for at least 9 units, may be counted as a restricted elective course toward the BME additional major.

42-201 Professional Issues in Biomedical Engineering

Fall and Spring: 3 units
This course exposes students to many of the issues that biomedical engineers face. It provides an overview of professional topics including bioethics, regulatory issues, communication skills, teamwork, and other contemporary issues. Outside speakers and case studies will describe real world problems and professional issues in biotechnology and bioengineering, and progress toward their solution.

42-202 Physiology

Fall and Spring: 9 units
This course is an introduction to human physiology and includes units on all major organ systems. Particular emphasis is given to the musculoskeletal, cardiovascular, respiratory, digestive, excretory, and endocrine systems. Modules on molecular physiology tissue engineering and physiological modeling are also included. Due to the close interrelationship between structure and function in biological systems, each functional topic will be introduced through a brief exploration of anatomical structure. Basic physical laws and principles will be explored as they relate to physiologic function. Prerequisite or co-requisite: 03-121 Modern Biology, or permission of instructor.
Prerequisites: 03-121 or 03-151

42-203 Biomedical Engineering Laboratory

Fall and Spring: 9 units
This laboratory course is designed to provide students with the ability to make measurements on and interpret data from living systems. The experimental modules reinforce concepts from 42-101 Introduction to Biomedical Engineering and expose students to four areas of biomedical engineering: biomedical signal and image processing, biomaterials, biomechanics, and cellular and molecular biotechnology. Several cross-cutting modules are included as well. The course includes weekly lectures to complement the experimental component. Pre-med students should register for 03-206. Priority for enrollment will be given to students who have declared the Additional Major in Biomedical Engineering.
Prerequisites: 42-101 and (03-121 or 03-151)

42-300 Junior BME Research Project

Fall and Spring
Research projects for juniors under the direction of a regular or adjunct BME faculty member. Arrangements may also be made via the Associate Head of BME for off-campus projects provided that a regular or adjunct BME faculty member agrees to serve as a co-advisor. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the research advisor. The agreement should be summarized in a two-page project description with sign-off by the research advisor and a copy submitted for review and filing with the BME Department. A final written report of the results is required. Units may vary from 9 to 12 according to the expected time commitment, with one unit corresponding to 1 hour of research per week. One (but not more than one) semester of research, if registered for at least 9 units, may be counted as a restricted elective course toward the BME additional major.

42-302 Biomedical Engineering Systems Modeling and Analysis

Fall and Spring: 9 units
This course will prepare students to develop mathematical models for biological systems and for biomedical engineering systems, devices, components, and processes and to use models for data reduction and for system performance analysis, prediction and optimization. Models considered will be drawn from a broad range of applications and will be based on algebraic equations, ordinary differential equations and partial differential equations. The tools of advanced engineering mathematics comprising analytical, computational and statistical approaches will be introduced and used for model manipulation.
Prerequisites: 21-260 or 18-202 or 06-262

42-400 Senior BME Research Project

Fall and Spring
Research projects for seniors under the direction of a regular or adjunct BME faculty member. Arrangements may also be made via the Associate Head of BME for off-campus projects provided that a regular or adjunct BME faculty member agrees to serve as a co-advisor. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the research advisor. The agreement should be summarized in a two-page project description with sign-off by the research advisor and a copy submitted for review and filing with the BME Department. A final written report of the results is required. Units may vary from 9 to 12 according to the expected time commitment, with one unit corresponding to 1 hour of research per week. One (but not more than one) semester of research, if registered for at least 9 units, may be counted as a restricted elective course toward the BME additional major.

42-401 Foundation of BME Design

Fall: 6 units
This course sequence introduces Biomedical Engineering students to the design of useful biomedical products to meet a specific medical need. Students will learn to identify product needs, how to specify problem definitions and to use project management tools. Methods to develop creativity in design will be introduced. The course sequence is comprised of two parts: 42-401 is offered in the Fall semester and provides the students the opportunity to form project teams, select and define a project, create a development plan, and complete an initial prototype. 42-402 is offered in the Spring semester is a full semester course and completes the plan that was developed in the fall semester. This course culminates in the completion of multiple prototypes, a poster presentation, and a written report.
Prerequisite: 42-101

42-402 BME Design Project

Spring: 9 units
This course sequence introduces Biomedical Engineering students to the design of useful biomedical products to meet a specific medical need. Students will learn to identify product needs, how to specify problem definitions and to use project management tools. Methods to develop creativity in design will be introduced. The course sequence is comprised of two parts: 42-401 is offered in the Fall semester and provides the students the opportunity to form project teams, select and define a project, create a development plan, and complete an initial prototype. 42-402 is offered in the Spring semester is a full semester course and completes the plan that was developed in the fall semester. This course culminates in the completion of multiple prototypes, a poster presentation, and a written report.

42-437 Biomedical Optical Imaging

Fall: 9 units
Biophotonics, or biomedical optics, is a field dealing with the application of optical science and imaging technology to biomedical problems, including clinical applications. The course introduces basic concepts in electromagnetism and light tissue interactions, including optical properties of tissue, absorption, fluorescence, and light scattering. Imaging methods will be described, including fluorescence imaging, Raman spectroscopy, optical coherence tomography, diffuse optical spectroscopy, and photoacoustic tomography. The basic physics and engineering of each imaging technique are emphasized. Their relevance to human disease diagnostic and clinical applications will be included, such as breast cancer imaging and monitoring, 3D retinal imaging, ways of non-invasive tumor detection, as well as functional brain imaging in infants. NOTE: 42-437 is intended for undergraduates only. Pre-requisite: 33-107 Physics II for Engineering Students or permission of the instructor.
Prerequisite: 33-142

42-444 Medical Devices

Fall: 9 units
This survey course is an introduction to the engineering, clinical, legal, regulatory and business aspects of medical device performance and failure. Topics covered include a broad range of successful medical devices in clinical use, as well as historical case studies of devices that were withdrawn from the market as a consequence of noted failures. In-depth study of specific medical devices will include cardiovascular, orthopedic, and neurological disciplines. We will study best practices employed in the clinical setting, principles governing the design processes, and modes of failure as a risk to the patient population. Additional lectures will provide fundamental topics concerning biomaterials used for implantable medical devices (metals, polymers, ceramics), biocompatibility, imaging, patient risks and mechanisms of failure (wear, corrosion, fatigue, fretting, etc.). The level of technical content will require junior standing for MCS and CIT students, a degree in science or engineering for non-MCS or non-CIT graduate students, or permission of the instructor for all other students.

42-447 Rehabilitation Engineering

Fall: 9 units
Rehabilitation engineering is the systematic application of engineering sciences to design, develop, adapt, test, evaluate, apply, and distribute technological solutions to problems confronted by individuals with disabilities. This course surveys assistive technologies designed for a variety functional limitations - including mobility, communication, hearing, vision, and cognition - as they apply to activities associated with employment, independent living, education, and integration into the community. This course considers not only technical issues in device development, but also the psychosocial factors and market forces that influence device acceptance by individuals and the marketplace. Open only to students with junior standing who have had at least one engineering class or by permission of instructor.

42-610 Introduction to Biomaterials

Spring: 9 units
Understanding the fundamentals of biomaterials structure-function relationships pertaining to material functions and to cell and tissue environments will be a prime goal. The course will be composed of lectures, readings, projects and technical writing assignments. The synthesis, characterization and functional properties of organic and inorganic biomaterials and the processes involved in their use in tissue engineering and regenerative medicine will be discussed. Fundamental issues related to the utility of biomaterials, including biomechanics, transport, degradability, biointerfaces and biocompatibility, stability, fate in the body will be covered, along with some of the basic approaches to characterization. Clinical applications for biomaterials and new directions in design and synthesis to achieve better biocompatibility will be emphasized.

42-611 Biomaterials

Spring: 12 units
This class serves as an overview of the landscape of biomaterial engineering and research. This course will cover the application of materials in biological environments, focusing on structure-processing-property relationships, engineering design principles, and how the biological environment affects the material properties. This course will focus on applications of a variety of materials that interface with biological systems including natural biopolymers, synthetic polymers, metals, and ceramics. Topics include considerations in molecular design of biomaterials, fundamentals of thermodynamic and kinetics relationships, the application of bulk and surface properties in the design of medical devices, and understanding tissue-biomaterials interactions. This course will discuss practical applications of materials in drug delivery, tissue engineering, biosensors, and other biomedical technologies. Students will be assessed with homework assignments and quizzes. At the end of the class, in teams, students will apply the concepts they have learned to write and present a focused review on a biomaterial design/concept that excites them.

42-612 Tissue Engineering

Spring: 12 units
This course will train students in advanced cellular and tissue engineering methods that apply physical, mechanical and chemical manipulation of materials in order to direct cell and tissue function. Students will learn the techniques and equipment of bench research including cell culture, immunofluorescent imaging, soft lithography, variable stiffness substrates, application/measurement of forces and other methods. Students will integrate classroom lectures and lab skills by applying the scientific method to develop a unique project while working in a team environment, keeping a detailed lab notebook and meeting mandated milestones. Emphasis will be placed on developing the written and oral communication skills required of the professional scientist. The class will culminate with a poster presentation session based on class projects. Pre-requisite: Knowledge in cell biology and biomaterials, or permission of instructor

42-613 Polymeric Biomaterials

Spring: 12 units
This course will cover aspects of polymeric biomaterials in medicine from molecular principles to device scale design and fabrication. Topics include the chemistry, characterization, and processing of synthetic polymeric materials; cell-biomaterials interactions including interfacial phenomena, tissue responses, and biodegradation mechanisms; aspects of polymeric micro-systems design and fabrication for applications in medical devices. Recent advances in these topics will also be discussed.

42-614 Stem Cell Engineering

Intermittent: 9 units
This course will give an overview over milestones of stem cell research and will expose students to current topics at the frontier of this field. It will introduce students to the different types of stem cells as well as environmental factors and signals that are implicated in regulating stem cell fate. The course will highlight techniques for engineering of stem cells and their micro-environment. It will evaluate the use of stem cells for tissue engineering and therapies. Emphasis will be placed on discussions of current research areas and papers in this rapidly evolving field. Students will pick a class-related topic of interest, perform a thorough literature search, and present their findings as a written report as well as a paper review and a lecture. Lectures and discussions will be complemented by practical lab sessions, including: stem cell harvesting and culture, neural stem cell transfection, differentiation assays, and immunostaining, polymeric microcapsules as advanced culture systems, and stem cell integration in mouse brain tissue. The class is designed for graduate students and upper undergraduates with a strong interest in stem cell biology, and the desire to actively contribute to discussions in the class.

42-615 Biomaterial Host Interactions in Regenerative Medicine

Intermittent: 12 units
This course will provide students with hands-on experience in investigating host responses to synthetic and naturally biomaterials used in regenerative medicine applications. Students will gain experience in the analysis of host responses to these biomaterials as well as strategies to control host interaction. Biomaterial biocompatibility, immune interactions, tissue healing and regeneration will be addressed. Students will integrate classroom lectures with laboratory skills evaluating host-material interactions in a laboratory setting. Laboratory characterization techniques will include cell culture techniques, microscopic, cytochemical, immunocytochemical and histological analyses. Prior knowledge in physiology is helpful.

42-616 Bio-nanotechnology: Principles and Applications

Fall: 9 units
Have you ever wondered what is nanoscience and nanotechnology and their impact on our lives? In this class we will go through the key concepts related to synthesis (including growth methodologies and characterizations techniques) and chemical/physical properties of nanomaterials from zero-dimensional (0D) materials such as nanoparticles or quantum dots (QDs), one-dimensional materials such as nanowires and nanotubes to two-dimensional materials such as graphene. The students will then survey a range of biological applications of nanomaterials through problem-oriented discussions, with the goal of developing design strategies based on basic understanding of nanoscience. Examples include, but are not limited to, biomedical applications such as nanosensors for DNA and protein detection, nanodevices for bioelectrical interfaces, nanomaterials as building blocks in tissue engineering and drug delivery, and nanomaterials in cancer therapy. This class is open for both undergraduate (junior/senior) and graduate students.

42-620 Engineering Molecular Cell Biology

Fall: 12 units
Cells are not only basic units of living organisms but also fascinating engineering systems that exhibit amazing functionality, adaptability, and complexity. Applying engineering perspectives and approaches to study molecular mechanisms of cellular processes plays a critical role in the development of contemporary biology. At the same time, understanding the principles that govern biological systems provides critical insights into the development of engineering systems. The goal of this course is to provide basic molecular cell biology for engineering students with little or no background in cell biology, with particular emphasis on integrating engineering concepts throughout the entire learning process of modern molecular and cellular biology. This course will prepare advanced undergraduate or graduate students with the essential knowledge and mindset for future research endeavors involving engineering biological systems at molecular and cellular levels. This course, besides introducing the fundamental biological knowledge, aims to enhance students' comprehension and appreciation of (1) how engineering approaches have led to our current understanding of molecular and cell biology; (2) what the available engineering approaches are that allow manipulation and even creation of biological systems at molecular, cellular and tissue levels; (3) what the current challenges are in molecular and cell biology that could be solved one day by engineering innovation. Course topics include the engineering of cellular components (DNA, RNA, protein, cell membrane, mitochondria, extracellular matrix) and cellular processes (metabolism, proliferation, cell death, tissue formation). Pre-requisites: None. Prior completion of 03-121 Modern Biology is suggested but not required.

42-621 Principles of Immunoengineering and Development of Immunotherapy Drugs

Fall: 9 units
This course will provide context for the application of engineering principles to modulate the immune system to approaches problems in human health. Basic understanding of the components and function of the innate and adaptive immune system. Students will leave with a basic understanding of immunology and of the engineering techniques used to develop and characterize immunotherapy systems. Where appropriate, we will discuss how immunoengineering fits into other disciplines of engineering such as mechanical, chemical, and materials science. Because the purpose of immunoengineering is disease treatment, we will discuss, the therapy pipeline, development of clinical trials and the FDA approval process. Immunotherapy will also be assessed within different disease contexts including cancer, infectious disease, allergies, prosthetics and implants, neuro and musculoskeletal disorders.

42-622 Bioprocess Design

Spring: 9 units
This course is designed to link concepts of cell culture, bioseparations, formulation and delivery together for the commercial production and use of biologically-based pharmaceuticals; products considered include proteins, nucleic acids, and fermentation-derived fine chemicals. Associated regulatory issues and biotech industry case studies are also included. The format of the course is a mixture of equal parts lecture, open discussion, and participant presentation. Course work consists of team-oriented problem sets of an open-ended nature and indivudual-oriented industry case studies. The goals of the course work are to build an integrated technical knowledge base of the manufacture of biologically based pharmaceuticals and U.S. biotechnology industry. Working knowledge of cell culture and modern biology, biochemistry and differential equations is assumed. Pre-requisite: 42-321 Cellular and Molecular Biotechnology or both 03-232 Biochemistry and 06-422 Chemical Reaction Engineering, or instructor permission.
Prerequisites: 03-232 or 42-321 or 06-422

42-623 Cellular and Molecular Biotechnology

Fall: 9 units
This course will provide students with an introduction to biotechnology in an engineering context. The focus will be on using microorganisms to prepare therapeutically and technologically relevant biochemicals. Topics to be covered include cellular and microbial metabolism, recombinant DNA methodologies, bioreactor design, protein separation and purification, and systems approaches to biotechnology. Prerequisites: (42-202 Physiology OR 03-121 Modern Biology OR 03-232 Biochemistry) AND (06-262 Mathematical Methods of Chemical Engineering OR 21-260 Differential Equations) OR permission of instructor.

42-624 Biological Transport and Drug Delivery

Spring: 9 units
Analysis of transport phenomena in life processes on the molecular, cellular, organ and organism levels and their application to the modeling and design of targeted or sustained release drug delivery technologies. Coupling of mass transfer and reaction processes will be a consistent theme as they are applied to rates of receptor-mediated solute uptake in cells, drug transport and biodistribution, and drug release from delivery vehicles. Design concepts underlying advances in nanomedicine will be described.

42-625 Surgery for Engineers

Spring: 9 units
This course explores the impact of engineering on surgery. Students will interact with clinical practitioners and investigate the technological challenges that face these practitioners. A number of visits to the medical center are anticipated for hands on experience with a number of technologies utilized by surgeons to demonstrate the result of advances in biomedical engineering. These experiences are expected to include microvascular surgery, robotic surgery, laparoscopic, and endoscopic techniques. Tours of the operating room and shock trauma unit will be arranged. If possible observation of an operative procedure will be arranged (if scheduling permits). Invited surgeons will represent disciplines including cardiovascular surgery, plastic and reconstructive surgery, surgical oncology, trauma surgery, minimally invasive surgery, oral and maxillofacial surgery, bariatric surgery, thoracic surgery, orthopedic surgery, and others. The Primary Instructor is Howard Edington, M.D., MBA System Chairman of Surgery, Allegheny Health Network. This course meets once a week for 3 hours. Several sessions will be held at the Medical Center, transport provided. Pre-requisite: Physiology 42-202 and one of the introductory engineering courses, 42-101, 06-100, 12-100. 18-100, 19-101, 24-101, or 27-100 Priority for enrollment is given to BME Graduate students and additional majors, followed by BME minors.
Prerequisites: 42-202 and (18-100 or 27-100 or 06-100 or 19-101 or 24-101 or 42-101 or 12-100)

42-626 Drug Delivery Systems

Fall and Spring: 9 units
The body is remarkable in its ability to sequester and clear foreign entities - whether they be "bad" (e.g. pathogens) or "good" (e.g. therapeutic drugs). This course will explore the design principles being used to engineer modern drug delivery systems capable of overcoming the body's innate defenses to achieve therapeutic effect. Specifically, we will study the chemistry, formulation, and mechanisms of systems designed to deliver nucleic acids, chemotherapeutics, and proteins across a variety of physiological barriers. Scientific communication plays a prominent role in the course, and students will have several opportunities to strengthen their communication skills through journal club presentations, proposal writing and constructive feedback. This is a graduate level course that is also open to undergraduate seniors.

42-630 Introduction to Neural Engineering

Spring: 12 units
Neural engineering sits at the interface between neuroscience and engineering, applying classical engineering approaches and principles to understand the nervous system and its function. Modern neural engineering techniques have been used to measure neural activity using tools based on light, electricity, and magnetism. The same tools for measurement can be redirected to modulate neural activity, and manipulate how an organism perceives, thinks, and acts. The course objectives are to familiarize students with a range of neural engineering approaches to investigating and intervening in the nervous system, emphasizing quantitative understanding and fundamental engineering concepts. The course will pair lectures and discussion with projects involving real neural data (Matlab-based exercises). Example projects could include finding visual responses in EEG data, or determining how groups of individual neurons interact based on spiking data. Overall, the goal is to give the student a deep understanding of select topics in neuroscience and the application of quantitative neural engineering approaches to these topics. This course is intended for advanced undergraduate and entering graduate students. Familiarity with linear algebra, signal processing, and introductory Matlab programming is helpful. This course is suitable for students coming from diverse backgrounds: (1) Students with non-engineering backgrounds seeking quantitative skills, and wanting to learn an engineering approach to neuroscience problems, and (2) students with engineering or other quantitative backgrounds who are seeking ways to apply their skills to scientific questions in neuroscience.

42-631 Neural Data Analysis

Fall: 12 units
The vast majority of behaviorally relevant information is transmitted through the brain by neurons as trains of actions potentials. How can we understand the information being transmitted? This class will cover the basic engineering and statistical tools in common use for analyzing neural spike train data, with an emphasis on hands-on application. Topics may include neural spike train statistics (Poisson processes, interspike intervals, Fano factor analysis), estimation (MLE, MAP), signal detection theory (d-prime, ROC analysis, psychometric curve fitting), information theory, discrete classification, continuous decoding (PVA, OLE), and white-noise analysis. Each topic covered will be linked back to the central ideas from undergraduate probability, and each assignment will involve actual analysis of neural data, either real or simulated, using Matlab. This class is meant for upper-level undergrads or beginning graduate students, and is geared to the engineer who wants to learn the neurophysiologist's toolbox and the neurophysiologist who wants to learn new tools. Those looking for broader neuroscience application (eg, fMRI) or more focus on regression analysis are encouraged to take 36-746. Those looking for more advanced techniques are encouraged to take 18-699. Prerequisites: undergraduate probability (36-225/227, or its equivalent), some familiarity with linear algebra and Matlab programming

42-632 Neural Signal Processing

Spring: 12 units
The brain is among the most complex systems ever studied. Underlying the brain's ability to process sensory information and drive motor actions is a network of roughly 10^11 neurons, each making 10^3 connections with other neurons. Modern statistical and machine learning tools are needed to interpret the plethora of neural data being collected, both for (1) furthering our understanding of how the brain works, and (2) designing biomedical devices that interface with the brain. This course will cover a range of statistical methods and their application to neural data analysis. The statistical topics include latent variable models, dynamical systems, point processes, dimensionality reduction, Bayesian inference, and spectral analysis. The neuroscience applications include neural decoding, firing rate estimation, neural system characterization, sensorimotor control, spike sorting, and field potential analysis. Prerequisites: 18-290; 36-217, or equivalent introductory probability theory and random variables course; an introductory linear algebra course; senior or graduate standing. No prior knowledge of neuroscience is needed.

42-638 Introduction to Biophotonics

Spring: 9 units
Biophotonics, or biomedical optics, is a field dealing with the application of optical science and imaging technology to biomedical problems, including clinical applications. The course introduces basic concepts in electromagnetism and light tissue interactions, including optical properties of tissue, absorption, fluorescence, and light scattering. Imaging methods will be described, including fluorescence imaging, Raman spectroscopy, optical coherence tomography, diffuse optical spectroscopy, and photoacoustic tomography. The basic physics and engineering of each imaging technique are emphasized. Their relevance to human disease diagnostic and clinical applications will be included, such as breast cancer imaging and monitoring, 3D retinal imaging, ways of non-invasive tumor detection, as well as functional brain imaging in infants. Pre-requisite: College level physics covering electromagnetism and optics or permission of the instructor.

42-639 Introduction to Neural Engineering

Intermittent: 12 units
Neural engineering sits at the interface between neuroscience and engineering, applying classical engineering approaches and principles to understand the nervous system and its function. Modern neural engineering techniques have been used to measure neural activity using tools based on light, electricity, and magnetism. The same tools for measurement can be redirected to modulate neural activity, and manipulate how an organism perceives, thinks, and acts. The course objectives are to familiarize students with a range of neural engineering approaches to investigating and intervening in the nervous system, emphasizing quantitative understanding and fundamental engineering concepts. The course will pair lectures and discussion with projects involving real neural data (Matlab-based exercises). Example projects could include finding visual responses in EEG data, or determining how groups of individual neurons interact based on spiking data. Overall, the goal is to give the student a deep understanding of select topics in neuroscience and the application of quantitative neural engineering approaches to these topics. This course is intended for advanced undergraduate and entering graduate students. Familiarity with linear algebra, signal processing, and introductory Matlab programming is helpful. This course is suitable for students coming from diverse backgrounds: (1) Students with non-engineering backgrounds seeking quantitative skills, and wanting to learn an engineering approach to neuroscience problems, and (2) students with engineering or other quantitative backgrounds who are seeking ways to apply their skills to scientific questions in neuroscience.

42-640 Image-Based Computational Modeling and Analysis

Spring: 12 units
Biomedical modeling and visualization play an important role in mathematical modeling and computer simulation of real/artificial life for improved medical diagnosis and treatment. This course integrates mechanical engineering, biomedical engineering, computer science, and mathematics together. Topics to be studied include medical imaging, image processing, geometric modeling, visualization, computational mechanics, and biomedical applications. The techniques introduced are applied to examples of multi-scale biomodeling and simulations at the molecular, cellular, tissue, and organ level scales.

42-641 Rehabilitation Engineering

Fall: 9 units
Rehabilitation engineering is the systematic application of engineering sciences to design, develop, adapt, test, evaluate, apply, and distribute technological solutions to problems confronted by individuals with disabilities. This course focuses on assistive technologies - technologies designed for use in the everyday lives of people with disabilities to assist in the performance of activities of daily living. The course surveys assistive technologies designed for a variety of functional limitations - including mobility, communication, hearing, vision, and cognition - as they apply to activities associated with employment, independent living, education, and integration into the community. This course considers not only technical issues in device development, but also the psychosocial factors and market forces that influence device acceptance by individuals and the marketplace. The class is designed for graduate students and upper undergraduates.

42-643 Microfluidics

Intermittent: 12 units
This course offers an introduction to the emerging field of microfluidics with an emphasis on chemical and life sciences applications. During this course students will examine the fluid dynamical phenomena underlying key components of "lab on a chip" devices. Students will have the opportunity to learn practical aspects of microfluidic device operation through hands-on laboratory experience, computer simulations of microscale flows, and reviews of recent literature in the field. Throughout the course, students will consider ways of optimizing device performance based on knowledge of the fundamental fluid mechanics. Students will explore selected topics in more detail through a semester project. Major course topics include pressure-driven and electrokinetically-driven flows in microchannels, surface effects, micro-fabrication methods, micro/nanoparticles for biotechnology, biochemical reactions and assays, mixing and separation, two-phase flows, and integration and design of microfluidic chips. Pre-requisites: 24-231 or 06-261 or 12-355 or instructor permission.

42-645 Cellular Biomechanics

Intermittent: 9 units
This course discusses how mechanical quantities and processes such as force, motion, and deformation influence cell behavior and function, with a focus on the connection between mechanics and biochemistry. Specific topics include: (1) the role of stresses in the cytoskeleton dynamics as related to cell growth, spreading, motility, and adhesion; (2) the generation of force and motion by moot molecules; (3) stretch-activated ion channels; (4) protein and DNA deformation; (5) mechanochemical coupling in signal transduction. If time permits, we will also cover protein trafficking and secretion and the effects of mechanical forces on gene expression. Emphasis is placed on the biomechanics issues at the cellular and molecular levels; their clinical and engineering implications are elucidated. 3 hrs. lec. Prerequisite: Instructor permission. Prerequisites: None. Corequisites: None. Cross Listed Courses: 24-655 Notes: None. Reservations:

42-648 Cardiovascular Mechanics

Spring: 12 units
The primary objective of the course is to learn to model blood flow and mechanical forces in the cardiovascular system. After a brief review of cardiovascular physiology and fluid mechanics, the students will progress from modeling blood flow in a.) small-scale steady flow applications to b.) small-scale pulsatile applications to c.) large-scale or complex pulsatile flow applications. The students will also learn how to calculate mechanical forces on cardiovascular tissue (blood vessels, the heart) and cardiovascular cells (endothelial cells, platelets, red and white blood cells), and the effects of those forces. Lastly, the students will learn various methods for modeling cardiac function. When applicable, students will apply these concepts to the design and function of selected medical devices (heart valves, ventricular assist devices, artificial lungs).

42-649 Introduction to Biomechanics

Fall: 12 units
The purpose of this course is to achieve a broad overview of the application of mechanics to the human body. This includes solid, fluid, and viscoelastic mechanics applied to single cells, the cardiovascular system, lungs, muscles, bones, and human movement. The physiology of each system will be reviewed as background prior to discussing mechanics applications within that system. Prior knowledge/experience in statics, fluid mechanics, and biology are helpful.

42-650 Introduction to Biomedical Imaging

Fall: 9 units
The field of medical imaging describes methods of seeing the interior of the human body, as well as visual representation of tissue and organ function. The materials covered in this course will give an overview of existing medical imaging devices used in a clinical and pre-clinical setting. The course presents the principles of medical imaging technologies, explaining the mathematical and physical principles, as well as describing the fundamental aspects of instrumentation design. Students will gain a thorough understanding of how these methods are used to image morphological and physiological features. Imaging methods will include Ultrasound, X-ray, computed tomography (CT), and magnetic resonance imaging (MRI), as well as optical methods. For each method, the fundamental imaging principles will be discussed, and examples of clinical applications will be presented. No prior knowledge of imaging methods is required.

42-652 Nano-Bio-Photonics

Spring: 12 units
Light can penetrate biological tissues non-invasively. Most of the available bio-optic tools are bulky. With the advent of novel nanotechnologies, building on-chip integrated photonic devices for applications such as sensing, imaging, neural stimulation, and monitoring is now a possibility. These devices can be embedded in portable electronic devices such as cell phones for point of care diagnostics. This course is designed to convey the concepts of nano-bio-photonics in a practical way to prepare students to engage in emerging photonic technologies. The course starts with a review of electrodynamics of lightwaves. The appropriate choice of wavelength and material platform is the next topic. Then optical waveguides and resonators are discussed. Resonance-based sensing is introduced followed by a discussion of the Figure of Merits (FOMs) used to design on-chip sensors. Silicon photonics is introduced as an example of a CMOS-compatible platform. On-chip spectroscopy is the next topic. The second part covers nano-plasmonics for bio-detection and therapy. The design methods are discussed, followed by an overview of nanofabrication and chemical synthesis, and then a discussion of applications. The last part of this course will be dedicated to a review of recent applications such as Optogenetic neural stimulation, Calcium imaging, Cancer Imaging and Therapy. Senior or graduate standing required. This course is cross-listed with 18416. Although students in 18-616 and 18-416 will share the same lectures and recitations, students in 18-616 will receive distinct course projects. Students in 18-416 and 18-616 will be graded on separate curves.

42-655 Biostatistics

Spring: 9 units
This course introduces statistical methods for making inferences in engineering, biology and medicine. Students will learn how to select the most appropriate methods, how to apply these methods to actual data, and how to read and interpret computer output from a commonly used statistical package. The topics covered are descriptive statistics; elementary probability; discrete and continuous random variables and their distributions; hypothesis testing involving interval (continuous and discrete) and categorical (nominal and ordinal) variables, for two and three or more treatments; simple and multiple linear regression; time-series analysis; clustering and classification; and time-to-event (survival) analysis. Students will also learn how to write the statistical component of a "Results" section for a scientific paper and learn about the limitations of the statistical analyses. Basic familiarity with probability and probability distribution preferred but not required.

42-656 Introduction to Machine Learning for Biomedical Engineers

Fall: 9 units
This course introduces fundamental concepts, methods and applications in machine learning and datamining. We will cover topics such as parametric and non-parametric learning algorithms, support vector machines, neural networks, clustering, clustering and principal components analysis. The emphasis will be on learning high-level concepts behind machine learning algorithms, and applying them to biomedical-related problems. This course is intended for advanced undergraduate and graduate students in Biomedical Engineering or related disciplines. Students should have experience with high-level programming language such as Python/Matlab, basic familiarity with probability, statistics and linear algebra, and should be comfortable with manipulating vectors and matrices.

42-660 Bioinstrumentation

Spring: 12 units
This course aims to build concepts and skills in electronics for the design and construction of instruments for biomedical applications. The course uses a flipped, fast-paced format to cover a range of electronic components and circuits, including resistors, capacitors, transistors, sensors, actuators, amplifiers, signal filters, and microcontrollers, through lectures, tutorials, weekly lab projects, and term projects. Students, with or without a background in electronics, will gain hands-on skills to build functional instruments for physiological measurements such as temperature, gas concentration, blood pressure, and EKG signals.

42-661 Surgery for Engineers

Spring: 9 units
This course explores the impact of engineering on surgery. Students will interact with clinical practitioners and investigate the technological challenges that face these practitioners. A number of visits to the medical center are anticipated for hands on experience with a number of technologies utilized by surgeons to demonstrate the result of advances in biomedical engineering. These experiences are expected to include microvascular surgery, robotic surgery, laparoscopic, and endoscopic techniques. Tours of the operating room and shock trauma unit will be arranged. If possible observation of an operative procedure will be arranged (if scheduling permits). Invited surgeons will represent disciplines including cardiovascular surgery, plastic and reconstructive surgery, surgical oncology, trauma surgery, minimally invasive surgery, oral and maxillofacial surgery, bariatric surgery, thoracic surgery, orthopedic surgery, and others. The Primary Instructor is Howard Edington, M.D., MBA System Chairman of Surgery, Allegheny Health Network. This course meets once a week for 3 hours. Several sessions will be held at the Medical Center, transport provided. Pre-requisite: Physiology 42-202 and one of the introductory engineering courses, 42-101, 06-100, 12-100. 18-100, 19-101, 24-101, or 27-100 Priority for enrollment is given to BME Graduate students and additional majors, followed by BME minors.
Prerequisites: 42-202 and (27-100 or 24-101 or 19-101 or 18-100 or 12-100 or 06-100 or 42-101)

42-663 Computational Methods in BME

Spring: 12 units
This goal of this course is to enable students with little or no programming background to solve simple computational problems in science and engineering. Emphasis will be placed on enabling students to use currently available numerical methods (rather than developing anew) to solve engineering problems. Upon completing the course, the successful student will be able to use basic knowledge regarding computer architecture, data types, binary arithmetic, and programming, to solve sample quantitative problems in engineering. Topics will include: solving linear systems of equations, model fitting using least squares techniques (linear and nonlinear), data interpolation, numerical integration and differentiation, solving differential equations, and data visualization. Specific example computations in each topic above will be drawn from problems in physics, chemistry, as well as signal and image processing, and biomedical engineering. Students will work independently in groups for a final project. Matlab will be used as the programming language/environment for this class, although different languages such as C, Java, and Python will be briefly discussed (time permitting). May count as practicum for practicum-option MS. Pre-requisite: Calculus, multivariate calculus, linear algebra, and differential equations

42-665 Brain-Computer Interface: Principles and Applications

Spring: 9 units
This course provides an introduction and comprehensive review of the concepts, principles and methods of Brain-computer interface (BCI) technology. BCIs have emerged as a novel technology that bridges the brain with external devices. BCIs have been developed to decode human intention, leading to direct brain control of a computer or device, bypassing the neuromuscular pathway. Bi-directional brain-computer interfaces not only allows device control, but also opens the door for modulating the central nervous system through neural interfacing. Using various recorded brain signals that reflect the "intention" of the brain, BCI systems have shown the capability to control external devices, such as computers and robots. Neural stimulation using electrical, magnetic, optical and acoustic energy has shown capability to better understanding of the brain functions and intervene with central nervous systems. This course teaches the fundamentals how a BCI system works and various building blocks of BCIs, from signal acquisition, signal processing, feature extraction, feature translation, neurostimulation, to device control, and various applications. Examples of noninvasive BCIs are discussed to provide an in-depth understanding of the noninvasive BCI technology. Open to seniors or graduate students in engineering or science programs, or upon instructor's approval (for exceptional juniors, e.g.).

42-666 Neuroengineering Practicum

Fall: 9 units
This course will examine topics and issues related to ethics, professional conduct, conflicts, plagiarism, copyright, authorship, research design considerations, IRB, IACUC, intellectual properties, review process, regulatory science and FDA process, professional presentations, and technical writing in neuroengineering. Students will discuss neuro-ethical implications of neural technologies and learn about the process of bringing such technologies to market, including intellectual property and FDA approval considerations. Students will discuss essential career development skills for a neuroengineering R and D career in academia and industry. An important component of the course is to develop students' communications skills including developing an effective research proposal, as well as effective oral presentations of the ideas developed in the proposal and technical report. The essentials for successful proposal writing will be discussed in case studies, in the form of fellowship applications. Each student will be required to develop a research proposal based upon students' own research or an emerging research topic in neuroengineering. Each student will also be required to develop a research statement on her/his own research interest. It is expected that students will improve her/his writing skills for proposal/research statement development with case studies, group discussions, and individualized feedbacks on students' own writing and presentation. This course will help students to develop practical skills addressing real world problems in neuroengineering.

42-667 Biofabrication and Bioprinting

Spring: 12 units
This laboratory course is designed to introduce students to and give them hands-on experience using methods that are used to fabricate scaffolds that are often used in tissue engineering, drug delivery, and some medical devices. Methods that will be taught include plastic FDM (filament deposition methods) to 3d print thermoplastic materials and molds for casting soft hydrogel materials, as well as 3d Bioprinting of soft hydrogel materials into a support bath material. This course will include a lecture component to introduce students to the concepts needed to design and fabricate the scaffolds. Lecture topics will include (but are not limited to): chemical and physical properties of biomaterials, CAD, and post-processing methods. There are no pre-requisite courses; however prior introductory lab experience is suggested.

42-668 "Fun"-damentals of MRI and Neuroimaging Analysis

Spring: 9 units
Neuroimaging gives us many ways to learn how the brain operates through various functions and disease states without having to perform any invasive surgery. This course will cover the methodology and analysis of structural magnetic resonance imaging (MRI) and functional MRI in humans and animals. Through lecture, discussion and analysis of sample data, students will understand the (A) history of MRI, (B) physics of MRI, (C) utilization with MRI and other devices used to interpret biological tissue, (D) how to design an fMRI experiment, and (E) analysis techniques in MRI. At the end of the course, students will have strong fundamental MRI and fMRI skillset and gain programming skills in MATLAB and learn other tools like SPM to process MRI and fMRI datasets in appropriate software packaging.

42-669 Energy Applications in Biology and Medicine

Spring: 12 units
This course covers a wide range of energy-based applications in biology and medicine, such as cancer treatments by cryosurgery (freezing), thermal ablation (heating), photodynamic therapy (light-activated drugs), and irreversible electroporation (a non-thermal electrical application). This course also covers thermal regulation in humans and other mammals, as well as cryopreservation (low-temperature preservation) of tissues and organs for the benefit of organ banking and transplant medicine. The course combines lectures and individual assignments relating to the underlying principles of engineering, with teamwork on open-ended projects relating to concurrent challenges at the convergence of engineering and medical sciences. The course plan assumes a mastery of the fundamentals of heat transfer at the undergraduate level.

42-670 Special Topics: Biomaterial Host Interactions in Regenerative Medicine

Intermittent: 12 units
Special Topics: This course will provide students with hands-on experience in investigating host responses to synthetic and naturally biomaterials used in regenerative medicine applications. Students will gain experience in the analysis of host responses to these biomaterials as well as strategies to control host interaction. Biomaterial biocompatibility, immune interactions, tissue healing and regeneration will be addressed. Students will integrate classroom lectures with laboratory skills evaluating host-material interactions in a laboratory setting. Laboratory characterization techniques will include cell culture techniques, microscopic, cytochemical, immunocytochemical and histological analyses. Prerequisite: junior or senior standing in Biomedical Engineering or consent of the instructor.

42-671 Precision Medicine for Biomedical Engineers

Fall: 9 units
This course explores the opportunities for engineers in precision medicine of complex medical disorders. Students will interact with clinical practitioners and investigate the technological challenges that face these practitioners. The course will focus on common complex conditions and diseases such as inflammatory bowel disease (IBD), pancreatitis, diabetes mellitus and obesity, rheumatoid arthritis, multiple sclerosis, pain syndrome and pharmacogenetics. Improvement in care of these conditions requires a reverse engineering approach, and new tools because of the complexity and unpredictability of clinical course and best treatments on a case-by-case basis. Currently, the cost of medications for these conditions in Pittsburgh alone is and gt;1 billion, with a large percent of patients receiving less than optimal treatment because of lack of precision medicine tools. The course includes introduction to medical genetics, biomarkers of disease, health records, disease modeling, outcome predictions, therapies, remote monitoring and smart applications. Special lectures on health economics and career opportunities are also planned. Each session will include didactic lectures, workshops and development of applications. Specific engineering topics which may be relevant to each of these specialties as well as topics which span many specialties (for example biodetectors, computational biology, bioinformatics, UI/UX, gaming ideas to connect patients to products, integrated applications) will be presented by various faculty members of the CMU biomedical engineering and other dept. and UPMC/UPitt faculty. Students will gain experience exploring genetic variants associated with common diseases, including the opportunity to explore their own DNA. Instructors: David C. Whitcomb, MD, PhD (UPMC) Philip Empey, PharmD, PhD (UPMC)

42-672 Fundamentals of Biomedical Imaging and Image Analysis

Spring: 12 units
This course introduces fundamentals of biological and medical imaging modalities and related image analysis techniques. It is organized into three units. The first unit introduces fundamental principles of biological imaging modalities, such as fluorescence microscopy, super-resolution microscopy, and electron microscopy. These modalities are used to visualize and record biological structures and processes at the molecular and cellular levels. The second unit introduces fundamental principles of imaging modalities, such as magnetic resonance imaging, x-ray computed tomography, and ultrasound. These modalities are used to visualize and record medical structures and processes at the tissue and organ levels. Recent developments in convergence of biological and medical imaging are briefly discussed. The third section introduces fundamentals of computational techniques used for analyzing and understanding biological and medical images, such as deconvolution, registration, segmentation, tracking, and pattern recognition. The introduction to these topics will draw on concepts and techniques from several related fields, including physics, statistics, signal processing, computer vision, and machine learning. As part of the course, students will complete several independent projects. Students will also have the opportunity to visit laboratories to see some of the actual biomedical imaging devices in action. Prerequisites: 18-290 Signals and Systems or permission of the instructor. Proficiency in basic programming is expected. Knowledge of image processing, computer vision, and/or MATLAB is helpful but not essential.

42-673 Special Topics: Stem Cell Engineering

Intermittent: 9 units
Special Topics: This course will give an overview over milestones of stem cell research and will expose students to current topics at the frontier of this field. It will introduce students to the different types of stem cells as well as environmental factors and signals that are implicated in regulating stem cell fate. The course will highlight techniques for engineering of stem cells and their micro-environment. It will evaluate the use of stem cells for tissue engineering and therapies. Emphasis will be placed on discussions of current research areas and papers in this rapidly evolving field. Students will pick a class-related topic of interest, perform a thorough literature search, and present their findings as a written report as well as a paper review and a lecture. Lectures and discussions will be complemented by practical lab sessions, including: stem cell harvesting and culture, neural stem cell transfection, differentiation assays, and immunostaining, polymeric microcapsules as advanced culture systems, and stem cell integration in mouse brain tissue. The class is designed for graduate students and upper undergraduates with a strong interest in stem cell biology, and the desire to actively contribute to discussions in the class.

42-674 Special Topics: Engineering for Survival: ICU Medicine

Intermittent: 9 units
Special Topics: Engineering for Survival: ICU Medicine The overall learning objective of this class is to expose students to acute care medicine and the fundamentals of acute illness. The lectures review the structure and function of different body systems. Typical modes of failure (disease) are then described and illustrated with examples using actual de-identified cases based on over 30 years of experiences in the intensive care unit (ICU) by Dr. Rosenbloom. Field trips are made to a local critical care and emergency medicine simulation facility at the University of Pittsburgh. An optional opportunity to participate in ICU rounds is also available. Requirements: Junior standing and higher

42-675 Fundamentals of Computational Biomedical Engineering

Fall: 12 units
This goal of this course is to enable students with little or no programming background to use computational methods to solve basic biomedical engineering problems. Students will use MATLAB to solve linear systems of equations, model fit using least squares techniques (linear and nonlinear), interpolate data, perform numerical integration and differentiation, solve differential equations, and visualize data. Specific examples for each topic will be drawn from different areas of biomedical engineering, such as bioimaging and signal processing, biomechanics, biomaterials, and cellular and biomolecular technology.

42-676 Bio-nanotechnology: Principles and Applications

Fall: 9 units
Have you ever wondered what is nanoscience and nanotechnology and their impact on our lives? In this class we will go through the key concepts related to synthesis (including growth methodologies and characterizations techniques) and chemical/physical properties of nanomaterials from zero-dimensional (0D) materials such as nanoparticles or quantum dots (QDs), one-dimensional materials such as nanowires and nanotubes to two-dimensional materials such as graphene. The students will then survey a range of biological applications of nanomaterials through problem-oriented discussions, with the goal of developing design strategies based on basic understanding of nanoscience. Examples include, but are not limited to, biomedical applications such as nanosensors for DNA and protein detection, nanodevices for bioelectrical interfaces, nanomaterials as building blocks in tissue engineering and drug delivery, and nanomaterials in cancer therapy. This class is open for both undergraduate (junior/senior) and graduate students.

42-678 Medical Device Innovation and Realization

Spring: 12 units
The increasing pace of medical discoveries and emerging technologies presents a unique and exciting time for medical devices. Medical devices range from biomaterials that stimulate the body to repair itself to drug eluting stints to robotic surgical systems. Because they seek to improve and prolong human health, there are unique requirements and challenges for medical device development compared to most other industries. This class will look at how medical device innovation is currently practiced as well as the drivers which govern it, such as the FDA, intellectual property, reimbursement, and funding. By the end of this course, students should be able to: (1) obtain a broad understanding of medical devices; (2) identify new product opportunities; (3) understand the drivers that affect medical device development; and (4) develop strategies to address those drivers within the overall medical device development plan.

42-681 Disease Models for Therapeutic Discovery

Spring: 9 units
One of the key challenges in the fields of tissue engineering and disease modelling is a disconnect between the use of robust bioengineering tools and our limited understanding of pathobiology. The future of these fields depends on biomedical engineers using their technical skill sets to study normal physiology and disease mechanisms. In this class, we will explore current state-of-the-art methods for creating tissue and disease models, including: 2D/3D tissue cultures, bioreactors, organs-on-a-chip, microfluidic models, disease-in-a-dish models (with discussions on coupling multiple tissue systems), animal models of disease, and CRISPR/CAS9. The first few weeks of the semester will focus on learning the state-of-the-art methods with 1 exam as an assessment. The rest of the class will focus on specific disease modules with journal reviews and experts sharing their research on disease models with the class. For assessment, students will read 1 journal article each week and provide a brief critique. In addition, they will write a grant and present to the class methods for creating a disease model of their choice. At the end of the class, students will be able to critically assess and design models of normal and pathobiological disease mechanisms. Prior knowledge of basic physiology is required.

42-682 Bioinstrumentation

Intermittent: 12 units
This course aims to build concepts and skills in electronics for the design and construction of instruments for biomedical applications. The course uses a flipped, fast-paced format to cover a range of electronic components and circuits, including resistors, capacitors, transistors, sensors, actuators, amplifiers, signal filters, and microcontrollers, through lectures, tutorials, weekly lab projects, and term projects. Students, with or without a background in electronics, will gain hands-on skills to build functional instruments for physiological measurements such as temperature, gas concentration, blood pressure, and EKG signals.

42-683 Introduction to Machine Learning for Biomedical Engineers

Fall: 9 units
This course introduces fundamental concepts, methods and applications in machine learning and datamining. We will cover topics such as parametric and non-parametric learning algorithms, support vector machines, neural networks, clustering, clustering and principal components analysis. The emphasis will be on learning high-level concepts behind machine learning algorithms, and applying them to biomedical-related problems. This course is intended for advanced undergraduate and graduate students in Biomedical Engineering or related disciplines. Students should have experience with high-level programming language such as Matlab, basic familiarity with probability, statistics and linear algebra, and should be comfortable with manipulating vectors and matrices.

42-684 Principles of Immunoengineering and Development of Immunotherapy Drugs

Fall: 9 units
This course will provide context for the application of engineering principles to modulate the immune system to approaches problems in human health. Basic understanding of the components and function of the innate and adaptive immune system. Students will leave with a basic understanding of immunology and of the engineering techniques used to develop and characterize immunotherapy systems. Where appropriate, we will discuss how immunoengineering fits into other disciplines of engineering such as mechanical, chemical, and materials science. Because the purpose of immunoengineering is disease treatment, we will discuss, the therapy pipeline, development of clinical trials and the FDA approval process. Immunotherapy will also be assessed within different disease contexts including cancer, infectious disease, allergies, prosthetics and implants, neuro and musculoskeletal disorders.

42-685 Biostatistics

Spring: 9 units
This course introduces statistical methods for making inferences in engineering, biology and medicine. Students will learn how to select the most appropriate methods, how to apply these methods to actual data, and how to read and interpret computer output from a commonly used statistical package. The topics covered are descriptive statistics; elementary probability; discrete and continuous random variables and their distributions; hypothesis testing involving interval (continuous and discrete) and categorical (nominal and ordinal) variables, for two and three or more treatments; simple and multiple linear regression; time-series analysis; clustering and classification; and time-to-event (survival) analysis. Students will also learn how to write the statistical component of a "Results" section for a scientific paper and learn about the limitations of the statistical analyses. Basic familiarity with probability and probability distribution preferred but not required.

42-687 AI Applications in BME

Spring: 12 units
This course provides hands-on experience in applying the fundamentals of artificial intelligence/machine learning (AI/ML) to problems in a variety of biomedical research areas and applications. Students will work in teams to design, develop, and evaluate an AI/ML system to achieve one or more of the following goals: identifying patterns in the data, modeling the input-output relationships and/or classifying data into distinct categories. The datasets for this course will be drawn from different BME-related areas provided by biomedical researchers, clinicians, and other publicly available sources. In addition to the project work, the course will discuss issues that are specific to the development and implementation of AI algorithms in medical settings. This includes FDA approval, human clinical trials, the Health Insurance Portability and Accountability Act, and medical ethics. This computational project-based course is available to any student who has completed Introduction to Machine Learning course.

42-688 Introduction to Neural Engineering

Intermittent: 12 units
Neural engineering sits at the interface between neuroscience and engineering, applying classical engineering approaches and principles to understand the nervous system and its function. Modern neural engineering techniques have been used to measure neural activity using tools based on light, electricity, and magnetism. The same tools for measurement can be redirected to modulate neural activity, and manipulate how an organism perceives, thinks, and acts. The course objectives are to familiarize students with a range of neural engineering approaches to investigating and intervening in the nervous system, emphasizing quantitative understanding and fundamental engineering concepts. The course will pair lectures and discussion with projects involving real neural data (Matlab-based exercises). Example projects could include finding visual responses in EEG data, or determining how groups of individual neurons interact based on spiking data. Overall, the goal is to give the student a deep understanding of select topics in neuroscience and the application of quantitative neural engineering approaches to these topics. This course is intended for advanced undergraduate and entering graduate students. Familiarity with linear algebra, signal processing, and introductory Matlab programming is helpful. This course is suitable for students coming from diverse backgrounds: (1) Students with non-engineering backgrounds seeking quantitative skills, and wanting to learn an engineering approach to neuroscience problems, and (2) students with engineering or other quantitative backgrounds who are seeking ways to apply their skills to scientific questions in neuroscience.

42-689 Introduction to Biomedical Imaging

Spring: 9 units
The field of medical imaging describes methods of seeing the interior of the human body, as well as visual representation of tissue and organ function. The materials covered in this course will give an overview of existing medical imaging devices used in a clinical and pre-clinical setting. The course presents the principles of medical imaging technologies, explaining the mathematical and physical principles, as well as describing the fundamental aspects of instrumentation design. Students will gain a thorough understanding of how these methods are used to image morphological and physiological features. Imaging methods will include Ultrasound, X-ray, computed tomography (CT), and magnetic resonance imaging (MRI), as well as optical methods. For each method, the fundamental imaging principles will be discussed, and examples of clinical applications will be presented. No prior knowledge of imaging methods is required.

42-690 BME in Everyday Life

Intermittent: 9 units
This course focuses on how biomedical engineering technologies are used in everyday life. The objective is to develop an understanding of the clinical need for these technologies, and past and current solutions to meet these clinical needs. Topics covered include artificial organs, tissue engineering, brain-control interfaces, and immunoengineering. For each medical condition being addressed, biology physiology, and anatomy concepts will be applied in the context of biomedical engineering technology. This course is suitable for non-engineering majors who have an interest in biomedical engineering.

42-691 Biomechanics of Human Movement

Spring: 12 units
This course provides an overview of the mechanical principles underlying human movement biomechanics and the experimental and modeling techniques used to study it. Specific topics will include locomotion, motion capture systems, force plates, muscle mechanics, musculoskeletal modeling, three dimensional kinematics, inverse dynamics, forward dynamic simulations, and imaging-based biomechanics. Homework and final class projects will emphasize applications of movement biomechanics in orthopedics, rehabilitation, and sports.
Prerequisites: 24-351 and 21-260

42-692 Special Topics: Nanoscale Manufacturing Using Structural DNA Nanotechnology

Fall: 12 units
This course provides an introduction to modern nanoscale manufacturing using structural DNAnanotechnology. This DNA-based approach to manufacturing has much in common with other fabrication methods in micro- and nano-engineering: computer aided design tools are necessary for device design and resulting structures can only be seen using advanced microscopy. However, instead of machining larger materials down to micro- and nanostructures, DNA origami is fabricated using a "bottom up" approach for self-assembling individual oligonucleotides into 2D and 3D nanostructures. Resulting structures can be designed to have novel mechanical and electrical properties and have applications as broad-ranging as medicine, biological computing, and energy systems. The course will include lectures, hands-on physical modeling, homework problems, 3D modeling of DNA origami using caDNAno and CANDO software, and student team projects and presentations.

42-693 Special Topics in Integrated Systems Technology: Micro/Nano Biomedical Devices

Fall: 12 units
Biomedical devices constantly call for innovations. Micro/nano fabrication not only miniaturizes devices and instruments, but also can enable new biomedical devices and significantly boost device performance. This course introduces fundamental micro/nano fabrication technologies and related materials of biomedical devices. The biomedical background and design principles of various biomedical devices will be presented. Both diagnostic and therapeutic devices will be discussed, including point-of-care diagnostic devices, biosensors, DNA sequencers, medical implants, prosthetic devices, drug delivery systems, medical robots, etc.

42-694 Engineering Principles of Medical Devices

Intermittent: 9 units
Medical devices are apparatuses widely used in diagnosis, treatment and prevention of human diseases. The invention and adoption of medical devices is one of the major driving forces for the revolution in modern healthcare. This course takes a systematic and quantitative approach for the design and implementation of medical devices. We will mainly focus on three major medical device categories: bioelectrical devices, biomechanical devices, and medical devices enabled by emerging technologies. For each category, domain knowledge and fundamental principles will be introduced, and detailed design, implementation, and performance analysis will be studied. Analytical equations and simulation tools will be used when appropriate. The course will prepare students with a solid foundation to further study, research, and work in medical device related fields. Pre-requisite or Co-requisite: 42-202 and (21-120 or 21-122 or 21-259) and (33-141 or 33-142) or permission of instructor

42-695 Special Topics: Engineering Protein Therapeutics

Intermittent: 12 units
The peptide/protein therapeutics market represents the fastest growing drug sector, addressing diseases that were incurable 20 years ago. These therapies are used to treat a broad range of disease states, including but not limited to cancer, metabolic, immunological, hematological, hormonal, genetic, and infectious diseases. The growth of these therapies is primarily driven by the increasing geriatric population and the growing prevalence of chronic diseases and the development of plasma-derived therapies, and also reflects advances in drug discovery. This course is meant to introduce peptide/protein therapeutic technologies to students with diverse backgrounds and will provide an understanding of the history, current state of the art and potential of these therapeutics. The course will consider major challenges associated with protein therapeutic including stability, immunogenicity, off-target effects, coformulation, and overcoming biological barriers, with a focus on clinical/commercial translation, considering not only manufacturing but delivery approaches, pharmacokinetic and pharmacological challenges.

42-696 Special Topics: Wearable Health Technologies

Spring: 12 units
This course will provide an overview of emerging wearable health technologies and give students hands-on experience in solving ongoing technical challenges. The wearable sensing field is experiencing explosive growth, with exciting applications in medicine. New lightweight devices will make it easier to monitor health conditions in real time, automatically import data into health informatics systems, and provide haptic feedback with humans in the loop. We will review several aspects of these technologies, including hardware, software, user experience, communication networks, applications, and big data analytics. Students will be paired with a company for a semester-long project that tackles timely computational challenges. Programing experience, in any language, is a pre-requisite.

42-697 Special Topics: Orthopaedic Tissue Mechanics

Spring: 9 units
In this course we will assess the composition, structure, function, failure, and repair of orthopaedic tissues, such as bone, cartilage, intervertebral disc, ligament, tendon, and meniscus. We will pay special attention to the analysis of composite materials, derivation of relevant analytical models, fitting of experimental data, and underlying assumptions. Students will have the opportunity to work in teams to assess seminal papers and explore unmet challenges in the field of orthopaedics. This course will prepare students who are interested in pursuing topics in the field of orthopaedics, rehabilitation, design of prosthetics, and tissue engineering. There are no prerequisites, but statics, dynamics, mechanics of materials, fluid mechanics, biomechanics, and biology are helpful.

42-713 Applied Nanoscience and Nanotechnology

Fall and Spring: 12 units
Have you ever wondered what is nanoscience and nanotechnology and their impact on our lives? In this class we will go through the key concepts related to synthesis (including growth methodologies and characterizations techniques) and chemical/physical properties of nanomaterials from zero-dimensional (0D) materials such as nanoparticles or quantum dots (QDs), one-dimensional materials such as nanowires and nanotubes to two-dimensional materials such as graphene. The students will then survey a range of applications of nanomaterials through problem-oriented discussions, with the goal of developing design strategies based on basic understanding of nanoscience. Examples include, but are not limited to, biomedical applications such as nanosensors for DNA and protein detection, nanodevices for bioelectrical interfaces, nanomaterials as building blocks in tissue engineering and drug delivery, and nano materials in cancer therapy. Pre-requisite: Graduate standing. College level chemistry or physical chemistry, and thermodynamics.

42-722 Bioprocess Design

Fall: 12 units
This course is designed to link concepts of cell culture, bioseparations, formulation, and delivery together for the commercial production and use of biologically-based pharmaceuticals; products considered include proteins, nucleic acids, and fermentation-derived fine chemicals. Associated regulatory issues and biotech industry case studies are also included. A fair knowledge of cell culture and fermentation operations is assumed.

42-733 Neural Technology: Sensing and Stimulation

Spring: 12 units
This course gives engineering insight into the operation of excitable cells, as well as circuitry for sensing and stimulation nerves. Initial background topics include diffusion, osmosis, drift, and mediated transport, culminating in the Nernst equation of cell potential. We will then explore models of the nerve, including electrical circuit models and the Hodgkin-Huxley mathematical model. Finally, we will explore aspects of inducing a nerve to fire artificially, and cover circuit topologies for sensing action potentials and for stimulating nerves. If time allows, we will discuss other aspects of medical device design. Students will complete a neural stimulator or sensor design project. Although students in 42-733 will share lectures and recitations with students in 42-433, students in 42-733 will receive some distinct homework assignments, distinct design problems, and distinct exams from the ones given to students in 42-433 and will be graded on a separate curve from students taking 42-433.

42-737 Biomedical Optical Imaging

Fall: 12 units
Biophotonics, or biomedical optics, is a field dealing with the application of optical science and imaging technology to biomedical problems, including clinical applications. The course introduces basic concepts in electromagnetism and light tissue interactions, including optical properties of tissue, absorption, fluorescence, and light scattering. Imaging methods will be described, including fluorescence imaging, Raman spectroscopy, optical coherence tomography, diffuse optical spectroscopy, and photoacoustic tomography. The basic physics and engineering of each imaging technique are emphasized. Their relevance to human disease diagnostic and clinical applications will be included, such as breast cancer imaging and monitoring, 3D retinal imaging, ways of non-invasive tumor detection, as well as functional brain imaging in infants.

42-772 Special Topics: Applied Nanoscience and Nanotechnology

Fall: 12 units
Have you ever wondered what is nanoscience and nanotechnology and their impact on our lives? In this class we will go through the key concepts related to synthesis (including growth methodologies and characterizations techniques) and chemical/physical properties of nanomaterials from zero-dimensional (0D) materials such as nanoparticles or quantum dots (QDs), one-dimensional materials such as nanowires and nanotubes to two-dimensional materials such as graphene. The students will then survey a range of applications of nanomaterials through problem-oriented discussions, with the goal of developing design strategies based on basic understanding of nanoscience. Examples include, but are not limited to, biomedical applications such as nanosensors for DNA and protein detection, nanodevices for bioelectrical interfaces, nanomaterials as building blocks in tissue engineering and drug delivery, and nano materials in cancer therapy. Pre-requisite: Graduate standing. College level chemistry or physical chemistry, and thermodynamics.

42-774 Special Topics: Introduction to Biophotonics

Fall: 12 units
Biophotonics, or biomedical optics, is a field dealing with the application of optical science and imaging technology to biomedical problems, including clinical applications. The course introduces basic concepts in electromagnetism and light tissue interactions, including optical properties of tissue, absorption, fluorescence, and light scattering. Imaging methods will be described, including fluorescence imaging, Raman spectroscopy, optical coherence tomography, diffuse optical spectroscopy, and photoacoustic tomography. The basic physics and engineering of each imaging technique are emphasized. Their relevance to human disease diagnostic and clinical applications will be included, such as breast cancer imaging and monitoring, 3D retinal imaging, ways of non-invasive tumor detection, as well as functional brain imaging in infants. Pre-requisite: Graduate standing. College level physics covering electromagnetism and optics or permission of the instructor.

42-783 Neural Engineering Laboratory

Intermittent: 12 units
Neural engineering applies classic engineering approaches and principles to understand the nervous system and its function. The measurement of neural activity involves a number of basic tools that have evolved over decades to sense the activity of neurons (individual neurons, populations of neurons and nerve fibers) or activity that is related to neurons (such as the oxygenation of blood in the brain). To intervene in the nervous system, a comparable set of tools have evolved to change neural activity locally or globally, on short and long time scales. The successful application of these methods to measure and manipulate neural activity requires both a basic science and engineering understanding of the principles behind their action, along with practical experience in applying them in real-world settings. This laboratory course will pair lectures with laboratory exercises to gain a deep understanding of the tools we use to measure and manipulate neural activity, as well as the analytic approaches to this data. It will involve both building and diagnosing recording hardware, experimental data collection, data analysis in Matlab or Python, and scientific writing. Overall, the goal is to provide students with a deep understanding of the methods for acquiring experimental data in neuroscience. Familiarity with signal processing and introductory Matlab or Python programming is helpful. This course is suitable for students from diverse backgrounds: (1) Students with experimental backgrounds seeking a range of hands-on experience in different experimental settings and a deeper understanding of different experimental methods, and (2) students with engineering and other quantitative backgrounds seeking exposure to experimental data collection methods and practices.

42-882 Tissue Engineering

Summer: 12 units
This course is currently only for those enrolled in the 3D Biofabrication and Bioprinting Certificate program. This course will train students in advanced cellular and tissue engineering methods that apply physical, mechanical and chemical manipulation of materials in order to direct cell and tissue function. Students will learn about the techniques and equipment of bench research including cell culture, immunofluorescent imaging, soft lithography, variable stiffness substrates, application/measurement of forces and other methods. Students will integrate classroom lectures and lab skills by applying the scientific method to develop a unique project while working in a team environment. Emphasis will be placed on developing the written and oral communication skills required of the professional scientist. The class will culminate with a poster presentation session based on class projects. Additionally, there will be a one week optional on campus experience for those who wish to practice hands-on cell culture skills but do not have access to facilities.

42-887 Biofabrication and Bioprinting

Spring: 12 units
This course is currently only for those enrolled in the 3D Biofabrication and Bioprinting Certificate program. This laboratory course is designed to introduce students to and give them hands-on experience using methods that are used to fabricate scaffolds that are often used in tissue engineering, drug delivery, and some medical devices. Methods that will be taught include plastic FDM (filament deposition methods) to 3d print thermoplastic materials and molds for casting soft hydrogel materials, as well as 3d Bioprinting of soft hydrogel materials into a support bath material. This course will include a lecture component to introduce students to the concepts needed to design and fabricate the scaffolds. Lecture topics will include (but are not limited to): chemical and physical properties of biomaterials, CAD, and post-processing methods. There are no pre-requisite courses; however prior introductory lab experience is suggested.

42-994 Special Topics: Technical Communication for Biomedical Engineers - Fellowship

Summer
This course is designed to teach graduate students in the Biomedical Engineering program principles of technical communication to solicit project support via NIH F31 Fellowship Application. Communication skills are foundational skillsets that will support biomedical researchers' technical goals and required regular practice to hone and enact throughout scientific careers. Students will work in a course setting, small peer review groups, and one-on-one with the instructor to complete their fellowship proposal. Students will also learn the standard components of advanced writing and revising tasks, including abstracts, literature reviews, reader reaction critiques, and a rhetorical approach to revision that support engineering work.

Department of Chemical Engineering

Carl Laird, Interim Department Head
Office: Doherty Hall 2100B
www.cheme.engineering.cmu.edu/ (http://
www.cheme.engineering.cmu.edu/)

Chemical Engineering is a broad discipline that combines chemistry, mathematics and physics with its own unique principles of *chemical engineering science* and *process systems engineering* to develop new products and manufacturing processes. Chemical engineering science refers to the material properties and models that help the chemical engineer understand and predict the transformation of chemical compounds at all stages of their conversion from raw materials to value added products. Process systems engineering provides methodologies for the systematic design, optimization, control, operation and analysis of a system of operations by which a product is manufactured, as well as the economic, safety, sustainability and environmental assessment of these processes.

Modern chemical engineering practice brings together a deep understanding of molecular properties and process design to not only develop more energy-efficient and sustainable manufacturing processes for currently existing products but also to develop new consumer and industrial products that provide enhanced functionality while making more efficient use of resources. As a result, the Chemical Engineering profession offers challenging and well-compensated careers in industries across the economy. Nearly all aspects of modern life use the products of chemical engineering. The pharmaceutical industry recruits chemical engineers to use their knowledge of chemical reaction engineering and separation processes to produce pure and effective pharmaceutical agents and drug delivery systems, and the biopharmaceutical industry attracts chemical engineers who can apply this expertise to biomanufacturing systems based on microbiology and biochemistry. In the chemical and energy sectors, chemical engineers develop catalysts and processes to improve yields in the production of commodity and specialty chemicals and fuels, and they develop new battery systems, fuel cells and biofuels to help build the renewable energy economy. Material manufacturers hire chemical engineers to develop large scale processes to synthesize polymers as resins for formulated products or as fabricated device components. The semiconductor industry seeks the chemical processing expertise of chemical engineers to manufacture chips, integrated circuits, and photovoltaic cells. Chemical engineers in the consumer products industries use their knowledge of chemical transformations to formulate and manufacture nearly all the products that people use in their everyday lives. Consulting companies seek chemical engineers for evaluation of the economic feasibility, environmental impact, and sustainability of industrial projects and to develop software for the design, analysis and operation of manufacturing processes. Finally, the curricular emphasis on the analysis and optimization of complex systems makes Chemical Engineering an excellent preparatory major for students interested in medical or business schools.

The Chemical Engineering curriculum develops deep problem solving skills through challenging, open-ended problems in chemical engineering science, process systems engineering, process system design and product design. Computing is integrated throughout the curriculum. The department supports extensive use of mathematical modeling and simulation software. Students in the Robert Rothfus Laboratory and Lubrizol Analytical Laboratory learn to use computerized data acquisition and control systems as they develop experimental tests of chemical engineering theory or process design alternatives. With its focus on complex chemical and biochemical processes, Chemical Engineering is a natural pairing with the Additional Major in Biomedical Engineering or the Biomedical Engineering minor. Chemical Engineering students pursue many different minors. It is particularly well aligned with the CIT Designated Minor in Colloids, Polymers and Surfaces and the University's Minor in Environmental and Sustainability Studies.

Program Educational Objectives and Student Outcomes

Program Educational Objectives

The Carnegie Mellon University Chemical Engineering Bachelor of Science degree program strives to produce graduates who:

- possess deep knowledge of chemical engineering fundamentals and the ability to combine them with advanced modeling and computational strategies to solve complex problems;
- strive for excellence in their professional activities, with a commitment to safety and ethical practices;
- understand the impact of their work in a global, economic, environmental, and societal context, which includes valuing the perspective of people with diverse backgrounds and experiences;
- are excellent communicators;
- excel both as leaders and as members of working teams; and
- are well prepared for immediate success in either professional employment or advanced education.

Learning Outcomes

Students who complete the Bachelor of Science in Chemical Engineering at Carnegie Mellon University will acquire:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics;
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors;
3. an ability to communicate effectively with a range of audiences;
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts;
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives;
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions; and
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

The department offers a number of special programs for students majoring in Chemical Engineering. In addition to the additional majors offered by the College of Engineering such as: Biomedical Engineering (BME), Engineering Design, Innovation & Entrepreneurship (EDIE), and Engineering & Public Policy (EPP), students may choose from a variety of minors in technical areas offered by the College of Engineering. Undergraduate research projects are also available in the areas of bioengineering, complex fluids engineering, environmental engineering, process systems engineering, and catalysis & surface science. The department offers the Chemical Engineering Summer Scholars (ChESS) program to support undergraduate research within the department. Students may participate in study abroad programs during their Junior year. In addition to the University Study Abroad programs, the department provides its own exchange programs with: RWTH Aachen in Germany, Imperial College in London, Great Britain, Universidad Nacional del Litoral in Argentina, and Yonsei University in Seoul, Korea. A summer exchange program in Dortmund, Germany is also available. Students may also participate in Practical Internships for Senior Chemical Engineering Students (PISCES), a one-year industrial internship program offered between the Junior and Senior years. Finally, qualified students may enroll in our Master of Chemical Engineering program. This degree is typically completed in the fifth year. However, depending on the number of advanced placement courses and course load at Carnegie Mellon, this degree could be awarded during the B.S. graduation, or after one additional semester.

Curriculum for Class of 2025 and Beyond

Minimum units required for B.S. in Chemical Engineering 391

The program in chemical engineering within the Department of Chemical Engineering is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the commission's General Criteria and Program Criteria for Chemical, Biochemical, Biomolecular, and Similarly Named Engineering Programs.

First Year

Fall		Units
21-120	Differential and Integral Calculus	10

76-xxx	Designated Writing/Expression Course	9
99-101	Core@CMU	3
06-100	Introduction to Chemical Engineering	12
09-105	Introduction to Modern Chemistry I	10
		44

Spring		Units
21-122	Integration and Approximation	10
xx-xxx	Introductory Engineering Elective (other than ChE)	12
33-141	Physics I for Engineering Students	12
xx-xxx	General Education Course	9
		43

Second Year

Fall		Units
21-254	Linear Algebra and Vector Calculus for Engineers	11
06-223	Chemical Engineering Thermodynamics	12
06-222	Sophomore Chemical Engineering Seminar	1
09-106	Modern Chemistry II	10
xx-xxx	Computer Sci./Physics II *	10-12
xx-xxx	General Education Course	9
39-210	Experiential Learning I	0
		53-55

Spring		Units
06-261	Fluid Mechanics	9
06-262	Mathematical Methods of Chemical Engineering	12
09-221	Laboratory I: Introduction to Chemical Analysis	12
xx-xxx	Physics II/Computer Sci. *	12-10
xx-xxx	General Education Course	9
39-220	Experiential Learning II	0
		54-52

* Computer Science/Physics II: Students should complete 15-110 Principles of Computing or 15-112 Fundamentals of Programming and Computer Science as well as 33-142 Physics II for Engineering and Physics Students by the end of the Sophomore year. The recommended sequence is 33-141 /33-142 for engineering students, however, 33-151/ 33-152 will also meet the CIT Physics requirement.

For those students who have not taken 06-100 as one of the two Introductory Engineering Electives, 06-100 should be taken in the Fall Semester of the Sophomore year. The General Education Course normally taken during that semester may be postponed until the Junior year. These students should consult with their advisor as soon as possible.

At the end of the Sophomore year, a student should have completed the following required basic science and computer science courses:

09-105	Introduction to Modern Chemistry I	10
09-106	Modern Chemistry II	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
15-110	Principles of Computing	10-12
or 15-112	Fundamentals of Programming and Computer Science	
33-141	Physics I for Engineering Students	12
33-142	Physics II for Engineering and Physics Students	12
99-101	Core@CMU	3

Third Year

Fall		Units
06-325	Numerical Methods and Machine Learning for Chemical Engineering	6
06-326	Optimization Modeling and Algorithms	6
06-322	Junior Chemical Engineering Seminar **	2
06-323	Heat and Mass Transfer	9
09-217	Organic Chemistry I	9-10
or 09-219	Modern Organic Chemistry	
06-310	Molecular Foundations of Chemical Engineering	9
xx-xxx	General Education Course	9
39-310	Experiential Learning III	0
		50-51

Spring		Units
06-361	Unit Operations of Chemical Engineering	9
06-363	Transport Process Laboratory	9
06-364	Chemical Reaction Engineering	9
xx-xxx	Advanced Chemistry Elective**/***	9
xx-xxx	Unrestricted Elective	9
xx-xxx	General Education Course	9
		54

Fourth Year

Fall		Units
06-421	Chemical Process Systems Design	12
06-423	Unit Operations Laboratory	9
xx-xxx	Unrestricted Elective	9
xx-xxx	Unrestricted Elective	9
xx-xxx	General Education Course	9
		48

Spring		Units
06-463	Chemical Product Design ****	9
06-464	Chemical Engineering Process Control	9
xx-xxx	Unrestricted Elective	9
xx-xxx	Unrestricted Elective	9
xx-xxx	General Education Course	9
		45

** For students pursuing Chemical Engineering with an Additional Major in Biomedical Engineering, the 06-322 Junior Chemical Engineering Seminar is replaced by 42-201 Professional Issues in Biomedical Engineering.
Students pursuing Chemical Engineering with an Additional Major in Engineering and Public Policy are waived from taking the Advanced Chemistry Elective. They will take 36-220.

*** **Advanced Chemistry Elective** may be any technical course offered by the Department of Chemistry for at least 9 units at the 200-level or above, or one of the following: 03-232 Biochemistry, 06-607 Physical Chemistry of Colloids and Surfaces, or 06-609/09-509 Physical Chemistry of Macromolecules. Students may petition the Undergraduate Committee to approve other chemistry-focused courses offered by other departments on a case-by-case basis.

**** The 06-463 Chemical Product Design requirement is waived for BME Additional Major students completing 42-401 Foundations of Biomedical Engineering Design (6 units, fall) AND 42-402 Biomedical Engineering Design Project (9 units, spring).

Notes:

1. In addition to the graduation requirement of an overall QPA of 2.0 (not counting the First Year), the Department of Chemical Engineering requires a cumulative QPA of 2.0 in all chemical engineering courses (all those numbered 06-xxx).
2. Minimum number of units required for graduation: 391.
3. All mathematics (21-xxx) courses required for the engineering degree taken at Carnegie Mellon must have a minimum grade of C in order to be counted toward the graduation requirement for the BS engineering degree.
4. A minimum grade of C must be achieved in any required mathematics (21-xxx) course that is a pre-requisite for the next higher level required mathematics (21-xxx) course.
5. Overloads are permitted only for students maintaining a QPA of 3.5 or better during the preceding semester.
6. Electives: To obtain a Bachelor of Science degree in Chemical Engineering, students must complete 06-100 and one other Introductory Engineering Elective. There are also five Unrestricted Electives.
7. Undergraduate Research: Independent research projects are available by arrangement with a faculty advisor. Many students conduct these research projects for elective credit by enrolling in 06-200, 06-300, or 06-400 (Sophomore, Junior, or Senior Research Projects) or 39-500 CIT Honors Research Project for eligible Seniors.

8. Advanced undergraduates may also take Chemical Engineering graduate courses (600 or 700 level).

Additional Major in Engineering and Public Policy (EPP)

Students may pursue an Additional Major in Chemical Engineering and EPP. This Additional Major is built around electives in Social Analysis, Probability and Statistics courses, and projects. Specific course choices should be discussed with the student's advisor and an EPP advisor.

Additional Major in Engineering Design, Innovation & Entrepreneurship (EDIE)

Students may pursue an Additional Major in Chemical Engineering and EDIE. Specific course choices should be discussed with the student's advisor and an EDIE advisor.

Additional Major in Biomedical Engineering (BME)

Students may pursue an Additional Major in Chemical Engineering and BME. Specific course choices should be discussed with the student's advisor and a BME advisor.

Minors with a B.S. in Chemical Engineering

Chemical Engineering students are eligible for any CIT Designated Minor. Those minors that are especially well suited to Chemical Engineers include: Additive Manufacturing, Audio Engineering, Biomedical Engineering, Colloids, Polymers & Surfaces, Electronic Materials, Global Engineering, Materials Science and Engineering and Mechanical Behavior of Materials. The minor requirements may be fulfilled with electives. Other minors, such as the Supply Chain Management minor in association with the Tepper School of Business or the Minor in Environmental and Sustainability Studies, are also available outside of CIT. These should be discussed with the student's advisor.

Colloids, Polymers and Surfaces Minor

Professor Robert Tilton, *Director of CPS Minor*
Location: Doherty Hall A207C

The sequence of courses in the Colloids, Polymers and Surfaces (CPS) designated minor provides an opportunity to explore the science and engineering of fine particles and macromolecules as they relate to complex fluids and interfacially engineered materials. These topics are very relevant to technology and product development in industries that manufacture pharmaceuticals, coatings and paints, pulp and paper, biomaterials, surfactants and cleaning products, cosmetics and personal care products, food, textiles and fibers, nanoparticles, polymer/plastics, composite materials.

Course Requirements

Minimum units required for minor: 45

This minor requires a total of five classes with a minimum of 45 units. The following four courses are mandatory:

06-609/09-509	Physical Chemistry of Macromolecules	9
06-607	Physical Chemistry of Colloids and Surfaces	9
06-426	Experimental Colloid Surface Science	9
06-466	Experimental Polymer Science	9

In addition, the student must take one CPS related elective course from the following list:

06-612	Formulation Engineering	12
06-610	Rheology and Structure of Complex Fluids	9
09-502	Organic Chemistry of Polymers	9
27-565	Nanostructured Materials	9
27-477	Introduction to Polymer Science and Engineering	9

Other CPS electives are possible but must be approved by the Director of the CPS minor, Professor Tilton

The Chemical Engineering curriculum develops deep problem solving skills through challenging, open-ended problems in chemical engineering science, process systems engineering, process system design and product design. Computing is integrated throughout the curriculum. The department supports extensive use of mathematical modeling and simulation software. Students in the Robert Rothfus Laboratory and Lubrizol Analytical Laboratory learn to use computerized data acquisition and control systems as they develop experimental tests of chemical engineering theory or process design alternatives. With its focus on complex chemical and biochemical processes, Chemical Engineering is a natural pairing with the Additional Major in Biomedical Engineering or the Biomedical Engineering minor. Chemical Engineering students pursue many different minors. It is particularly well aligned with the CIT Designated Minor in Colloids, Polymers and Surfaces and the University’s Minor in Environmental and Sustainability Studies.

Practical Internships for Senior Chemical Engineering Students (PISCES)

Chemical Engineering students may apply in the fall of their Junior year for a salaried, one-year PISCES internship with a partner company. Admitted students begin their internships after completion of the Junior year. Following the internship, students return to complete their Senior year. There are several advantages of a one full-year internship, including the opportunity to gain a breadth of professional experience that is not generally possible in a shorter program, more opportunity to make important contributions to the partner company, and the opportunity to complete Senior year courses in their normal sequence with no need for curriculum rearrangements. Interested students should consult with their advisor.

International Chemical Engineering Exchange Programs

Chemical Engineering students may apply during their Sophomore year to spend their Junior year at RWTH Aachen in Germany, Yonsei University in Seoul, Korea, Universidad Nacional del Litoral in Argentina, or at Imperial College in London, Great Britain. A summer exchange program in Dortmund, Germany is also available. These exchange programs provide a great opportunity for students to obtain international experience while taking courses very similar to those offered at Carnegie Mellon. Students considering any of these programs should consult with their advisor, and students considering the Aachen program in particular are advised to take at least one introductory German course before or during their Sophomore year.

Fifth Year Master of Chemical Engineering (MChE)

The CIT Integrated Masters/Bachelors (IMB) Degree program provides the opportunity for qualified undergraduate students to obtain a master's degree in Chemical Engineering with one or two extra semesters of study. The goal is to deepen our graduates' understanding of the fundamentals of chemical engineering, and to provide them with a broader set of professional skills or to expose them to other technical disciplines.

The MChE program is a 96 unit course work degree aimed at undergraduate students from Carnegie Mellon and candidates from other universities. No financial support is available. For Carnegie Mellon students, the degree typically would be completed in their fifth year. Depending on advanced placement and semester overloads, however, CMU students can complete the degree at the time of the B.S. graduation or with one additional semester. All students must have graduate status once they have completed their B.S. degree; beyond eight semesters, degree program students must have full-time graduate student status in at least one (e.g., their final) semester whether or not they have already completed their BS degree. Upon graduating from this program, students seek industrial positions or placement in graduate programs at other universities.

A minimum of five completed semesters in residence as an undergraduate student and an overall QPA of 3.0 is required for eligibility. Taking the GRE and recommendation letters are not required. The application fee is waived for currently-enrolled undergraduate Chemical Engineering students.

The MChE program differs from the MS program because the MChE program does not require a project report or thesis.

Faculty

SHELLEY ANNA, Vice Provost for Faculty and Professor of Chemical Engineering – Ph.D., Harvard University; Carnegie Mellon, 2003–

JOANNE BECKWITH MADDOCK, Assistant Teaching Professor of Chemical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2022–

LORENZ T. BIEGLER, Covestro University Professor and Professor of Chemical Engineering – Ph.D., University of Wisconsin; Carnegie Mellon, 1981–

DAPHNE WUI YARN CHAN, Assistant Professor of Chemical Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2022-–

MICHAEL M. DOMACH, Emeritus, Professor of Chemical Engineering – Ph.D., Cornell University; Carnegie Mellon, 1983–

NEIL M. DONAHUE, Lord University Professor of Chemistry and Chemical Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2000–

ANDREW J. GELLMAN, Lord Professor of Chemical Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 1992–

GABRIEL GOMES, Assistant Professor of Chemistry and Chemical Engineering – Ph.D., Florida State University; Carnegie Mellon, 2022–

HAMISH GORDON, Assistant Professor of Chemical Engineering – Ph.D., University of Oxford; Carnegie Mellon, 2022–

CHRYSANTHOS GOUNARIS, Professor of Chemical Engineering – Ph.D., Princeton University; Carnegie Mellon, 2013–

IGNACIO E. GROSSMANN, R. R. Dean University Professor of Chemical Engineering – Ph.D., Imperial College, University of London; Carnegie Mellon, 1979–

ANNETTE JACOBSON, Emeritus, Teaching Professor of Chemical Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1988–

COTY JEN, Assistant Professor of Chemical Engineering – Ph.D., University of Minnesota; Carnegie Mellon, 2018–

MYUNG S. JHON, Emeritus, Professor of Chemical Engineering – Ph.D., University of Chicago; Carnegie Mellon, 1980–

ADITYA KHAIR, Professor of Chemical Engineering – PhD, California Institute of Technology; Carnegie Mellon, 2010–

JOHN KITCHIN, Professor of Chemical Engineering – Ph.D., University of Delaware; Carnegie Mellon, 2006–

CARL LAIRD, Professor and Interim Department Head of Chemical Engineering – Ph.D., Carnegie Mellon; Carnegie Mellon, 2021–

ALEXANDRA NEWBY, Assistant Teaching Professor of Chemical Engienering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2024–

TAGBO NIEPA, Arthur Hamerschlag Associate Professor of Chemical Engineering – Ph.D., Syracuse University; Carnegie Mellon, 2023–

GRIGORIOS PANAGAKOS, Assistant Research Professor of Chemical Engineering – Ph.D., Technical University of Denmark; Carnegie Mellon, 2018–

ANNE SKAJA ROBINSON, Trustee Professor of Chemical Engineering – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2019–

JAMES W. SCHNEIDER, Professor of Chemical Engineering – Ph.D., University of Minnesota; Carnegie Mellon, 1999–

DERIN SEVENLER, Assistant Professor of Chemical Engineering – Ph.D., Boston University; Carnegie Mellon, 2024–

PAUL J. SIDES, Emeritus, Professor of Chemical Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 1981–

SUSANA C. STEPPAN, Emeritus, Associate Teaching Professor of Chemical Engineering – PhD, University of Massachusetts; Carnegie Mellon, 2004–

ROBERT D. TILTON, Chevron Professor of Chemical Engineering – Ph.D., Stanford University; Carnegie Mellon, 1992–

ANA INES TORRES, Assistant Professor of Chemical Engineering – Ph.D., University of Minnesota; Carnegie Mellon, 2022–

ARTHUR W. WESTERBERG, Emeritus, University Professor of Chemical Engineering – Ph.D., DIC, Imperial College, University of London; Carnegie Mellon, 1976–

KATHRYN WHITEHEAD, Professor of Chemical Engineering – Ph.D., University of California; Carnegie Mellon, 2012–

B. ERIK YDSTIE, Emeritus, Professor of Chemical Engineering – Ph.D., Imperial College, University of London; Carnegie Mellon, 1992–

Department of Chemical Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

06-100 Introduction to Chemical Engineering

Fall and Spring: 12 units
We equip students with creative engineering problem-solving techniques and fundamental chemical engineering material balance skills. Lectures, laboratory experiments, and recitation sessions are designed to provide coordinated training and experience in data analysis, material property estimation for single- and multi-phase systems, basic process flowsheet, reactive and non-reactive mass balances, problem solving strategies and tools, and team dynamics. The course is targeted for CIT First Year students.

06-150 First Year Research Project

Fall and Spring: 6 units
Research projects conducted by first year undergraduate students under the supervision of a Chemical Engineering faculty member. The nature of the project and the criteria for grading are to be determined between the student and the faculty supervisor. A final written report or an oral presentation of the results may be required. A commitment of six hours effort on the project per week is expected. Registration will be by permission only.

06-200 Sophomore Research Project

Fall and Spring
Research projects under the direction of the Chemical Engineering faculty. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the faculty supervisor. The agreement should then be summarized in a one-page project description for review by the faculty advisor of the student. A final written report or an oral presentation of the results is required.

06-222 Sophomore Chemical Engineering Seminar

Fall: 1 unit
This course provides an overview of the chemical engineering profession. It discusses the rationale for the curriculum, career paths, resume writing, written communication skills, and ethics, and also involves a project on the use and manufacture of chemicals.

06-223 Chemical Engineering Thermodynamics

Fall: 12 units
This course introduces students to thermodynamic state variables and the analysis of phase and chemical equilibrium in single- and multi-component chemical systems. Key topics include application of mass, energy and entropy balance equations to analyze processes with change of state and interconversion of energy between heat and work in open or closed systems; state property changes associated with phase change; equations of state to represent the pressure-volume-temperature relationship for pure materials and mixtures; Gibbs phase rule; phase equilibrium criteria; ideal and non-ideal mixtures; fugacity and prediction of pure liquid vapor pressure; fugacity and activity coefficients to predict multi-component vapor-liquid and liquid-liquid phase equilibrium; analysis of flash and other processes involving multi-component phase change; equilibrium constants and equilibrium conversions in chemically reacting systems.
Prerequisites: 06-100 and (33-141 or 33-151 or 33-121)

06-261 Fluid Mechanics

Spring: 9 units
The principles of fluid mechanics as applied to engineering, including unit operations, are discussed; examples include flow in conduits, process equipment, and commercial pipes, flow around submerged objects, and flow measurement. Microscopic mass and momentum balances are described, including the continuity and Navier-Stokes equations, and modern solution techniques will be explored. Microscopic flow structures will be determined for flow visualization. Boundary layer theory, turbulence, and non-Newtonian fluids are also discussed. A case-study project based on new technological advancements is also required.
Prerequisites: 21-254 and (33-151 or 33-121 or 33-141) and 06-223

06-262 Mathematical Methods of Chemical Engineering

Spring: 12 units
Mathematical techniques are presented as tools for modeling and solving engineering problems. Modeling of steady-state mass and energy balance problems using linear and matrix algebra, including Gaussian elimination, decomposition, and iterative techniques. Modeling of unsteady-state engineering problems using linear and nonlinear differential equations. Analytical techniques, including Laplace transforms, and numerical techniques for the solution of first-and higher-order differential equations and systems of differential equations arising in engineering models. Finally, the modeling of processes affected by chance and subject to experimental error; statistical and regression techniques within the context of experimental design and analysis of experimental data.
Prerequisites: 21-254 and 06-223

06-300 Junior Research Project

Fall and Spring
Research projects under the direction of the Chemical Engineering faculty. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the faculty supervisor. The agreement should then be summarized in a one-page project description for review by the faculty advisor of the student. A final written report or an oral presentation of the results is required.

06-310 Molecular Foundations of Chemical Engineering

Fall: 9 units
Students will learn to use the tools of molecular engineering that define the modern development of chemical engineering, using a combination of theory and computation. The theme throughout the course is the use of molecular engineering tools to specify alternative compositions and conditions for chemical engineering design. Applications will include the prediction of macroscopic transport properties and equations of state, and the ability to tune them via judicious specification of system composition; rate laws and rate constants for complex reacting systems, including multi-step heterogeneous and homogeneous reactions; and principles of non-covalent association and self-assembly in the context of sustainable chemical engineering product design. Students will investigate contemporary molecular engineering case studies focused on renewable energy, human health or solutions to environmental problems.
Prerequisites: 09-106 and 06-223

06-322 Junior Chemical Engineering Seminar

Fall: 2 units
This course discusses career choices for chemical engineers, professional practice, including alternate career paths, global industry, and graduate studies. It also emphasizes writing, interview skills, and oral presentations. Safety, environmental and ethical issues are illustrated in projects and via invited lectures.

06-323 Heat and Mass Transfer

Fall: 9 units
This course presents the fundamentals of heat and mass transfer, including steady-state and transient heat conduction and molecular diffusion, convection of heat and mass, and thermal radiation, with application to heat and mass transfer processes. Development of dimensionless quantities for engineering analysis is emphasized.
Prerequisites: 06-261 and (06-262 or 21-260) and (33-122 or 33-142 or 33-152)

06-325 Numerical Methods and Machine Learning for Chemical Engineering

Fall: 6 units
This course will focus on applying numerical methods and machine learning to chemical engineering problems. Students will learn how modern programming environments (on laptops and in the cloud) can run python code. Programming concepts such as defining functions and plotting quantities will be reviewed. Students will learn how to apply and debug numerical integration techniques to systems of ODEs. Solving systems of nonlinear equations and black-box optimization will be covered. Machine learning will be introduced starting with the statistics of linear and non-linear regression with regularization. Polynomial fitting and interpolation will be covered. With this base, students will learn how to apply machine learning techniques such as gaussian process regression and neural networks to regression tasks. A small project will be included near the end to encourage creative applications to chemical engineering problems.
Prerequisites: 06-262 and (15-112 or 15-110)

06-326 Optimization Modeling and Algorithms

Fall: 6 units
Formulation and solution of mathematical optimization problems with and without constraints. Objective functions are based on economics or functional specifications. Both discrete and continuous variables are considered.
Prerequisite: 06-262

06-361 Unit Operations of Chemical Engineering

Spring: 9 units
This course comprises many of the standard operations in chemical plants such as gas absorption, heat exchange, distillation and extraction. The design and operation of these devices is emphasized. A project dealing with a novel unit operation is also investigated.
Prerequisite: 06-323

06-363 Transport Process Laboratory

Spring: 9 units
Develop skills for proposing, designing, planning, implementing, interpreting, and communicating the results of experiments in fluid flow and heat and mass transfer. Oral and written reports are required.
Prerequisites: 06-261 and 06-323

06-364 Chemical Reaction Engineering

Spring: 9 units
Fundamental concepts in the kinetic modeling of chemical reactions, the treatment and analysis of rate data. Multiple reactions and reaction mechanisms. Analysis and design of ideal and non-ideal reactor systems. Energy effects and mass transfer in reactor systems. Introductory principles in heterogeneous catalysis.
Prerequisites: 06-323 and 06-310

06-400 Senior Research Project

Fall and Spring
Research projects under the direction of the Chemical Engineering faculty. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the faculty supervisor. The agreement should then be summarized in a one-page project description for review by the faculty advisor of the student. A final written report or an oral presentation of the results is required.

06-421 Chemical Process Systems Design

Fall: 12 units
Screening of processing alternatives. Computational strategies for preliminary material and energy balances in large chemical processes. Preliminary sizing of process equipment. Cost estimation, economics, and evaluation for chemical plants. Strategies for synthesizing energy networks and separation sequences. Preliminary design of a large industrial project.
Prerequisites: 06-364 and 06-361

06-423 Unit Operations Laboratory

Fall: 9 units
Open-ended laboratory projects illustrate the principles of unit operations in Chemical Engineering. In this course students select, with course staff review, current societal problems to which chemical engineering subject knowledge can be applied. Students work in teams to design and implement an experimental plan to evaluate proposed solutions. Teams must work together to identify constraints and relationships between the unit operations they work on. Students must document implementation feasibility (cost, scheduling, analytic capability, etc.) and clearly identify the criteria and methods for assessing experimental results. Oral and written reports are required.
Prerequisites: 06-361 and 06-364

06-426 Experimental Colloid Surface Science

Fall: 9 units
Laboratory exercises will deal with preparation and stabilization of colloids, flocculation, micellar aggregates, surface tension, contact angle, spreading and adsorption. Basic concepts will be related to practical problems of wetting, lubrication, foaming, adhesion, coatings and corrosion.
Prerequisites: 09-221 and 06-607

06-463 Chemical Product Design

Spring: 9 units
Computer-aided design of a chemical product. Course involves design of molecular structure, microstructure, or devices/processes that effect chemical change. This is a project-based course, for which an extensive report must be submitted.
Prerequisite: 06-421

06-464 Chemical Engineering Process Control

Spring: 9 units
This course presents basic concepts of process dynamics and feedback control. Included are selection of measurements and manipulated variables, definition of transfer functions, creation of block diagrams and closed loop configurations. The course also covers concepts of open loop and closed loop stability, and tuning of PID controllers.
Prerequisite: 06-325

06-466 Experimental Polymer Science

Spring: 9 units
Macromolecular behavior in bulk and in solution will be explored in experiments on tensile strength, elasticity, swelling of networks, solution viscosity, melt flow, and polymerization reactions. Particular reference will be made to aspects affecting production and fabrication of polymeric materials.
Prerequisites: 09-221 and (06-609 or 09-509)

06-606 Computational Methods for Large Scale Process Design & Analysis

Spring: 9 units
This course deals with the underlying computer-aided design techniques for steady-state and dynamic simulation, numerical solution and decomposition strategies for large systems of sparse nonlinear algebraic equations, stiff ordinary differential equations, strategies for mixed algebraic/differential systems and computer architectures for flowsheeting systems.
Prerequisites: 06-262 and 06-361

Course Website: http://numero.cheme.cmu.edu/course/06606.html

06-607 Physical Chemistry of Colloids and Surfaces

All Semesters: 9 units
Thermodynamics of surfaces; adsorption at gas, liquid, and solid interfaces; capillarity; wetting, spreading, lubrication and adhesion; properties of monolayers and thin films; preparation and characterization of colloids; colloidal stability, flocculation kinetics, micelles, electrokinetic phenomena and emulsions.

06-609 Physical Chemistry of Macromolecules

Fall: 9 units
This course develops fundamental principles of polymer science. Emphasis is placed on physio-chemical concepts associated with the macromolecular nature of polymeric materials. Engineering aspects of the physical, mechanical and chemical properties of these materials are discussed in relation to molecular structure. Topics include an introduction to polymer science and a general discussion of commercially important polymers; molecular weight; condensation and addition synthesis mechanisms with emphasis on molecular weight distribution; solution thermodynamics and molecular conformation; rubber elasticity; and the rheological and mechanical properties of polymeric systems. Students not having the prerequisite listed may seek permission of the instructor.

06-610 Rheology and Structure of Complex Fluids

Fall: 9 units
This course will cover the basic concepts of rheology and mechanical behavior of fluid systems. Both the experimental and theoretical aspects of rheology will be discussed. The basic forces influencing complex fluid rheology and rheology will be outlined and discussed; including excluded volume, van der Waals, electrostatic and other interactions. Methods of characterizing structure will be covered including scattering techniques, optical polarimetry and microscopy. Examples will focus on several types of complex fluids including polymer solutions and melts, gelling systems, suspensions and self-assembling fluids.

06-612 Formulation Engineering

Intermittent: 12 units
Students will learn the scientific and design principles needed for careers in complex fluid formulation-based industries such as consumer products, pharmaceuticals, paints, agrochemicals or lubricants. The essential science and engineering principles of colloids, surfactants, interfaces and polymer solutions will be introduced. Students will learn to use these principles in combination with experimental measurements and statistical design of experiments tools to design effective liquid product formulations within specified economic, material and even aesthetic constraints. The lecture portion of the course is complemented by weekly lab sessions where student teams will design, prepare, test and improve their own formulations for a commercial complex fluid product, such as a detergent or an ink, that meets performance goals within specified constraints.

06-614 Special Topics: Atmospheric Nanoparticles and Climate

Fall and Spring: 12 units
This course will examine the physicochemical properties of atmospheric nanoparticles and the chemical processes that form these particles. We will also cover basic techniques for characterizing atmospheric nanoparticles using fundamentals of aerosol physics and chemistry. The last portion of the course will explore how atmospheric nanoparticles affect the Earth's radiative budget and ultimately climate. Students will apply their atmospheric nanoparticle knowledge to determine the feasibility and effectiveness of various atmospheric geoengineering techniques proposed in literature. Though this course targets atmospheric nanoparticles, it is also broadly applicable to anyone interested applications of aerosolized nanoparticles. Prerequisites: undergraduate chemistry and physics

06-623 Mathematical Modeling of Chemical Engineering Processes

Fall: 12 units
Numerical approaches to solving problems relevant to chemical engineering applications. In this course, advanced mathematical topics relevant to chemical engineering will be used to solve complex problems. Topics include linear algebra, nonlinear equation solving, initial value and boundary value problems for solution of differential equations, numerical optimization, probability and stochastic methods. Significant focus will be placed on numerical rather than analytical solution to problems. Primary Software Package(s): Mathematical programming environment.

06-625 Chemical and Reactive Systems

Fall: 12 units
In this course process simulation software will be used to develop models of chemical and reactive systems. The models will be used to predict the performance of the system, as well as to probe how process modifications, e.g. process conditions, reactor types or sequences, etc. affect system performance. The effects of the underlying thermodynamic and kinetic databases of chemical properties on the performance predictions will be explored. Methods to incorporate new thermodynamic and kinetic data into chemical and reactive system simulations will be examined. Thermochemical and kinetic data for reactions will be estimated for use in process simulation software. Primary Software Package(s): Molecular modeling and process simulation software.

06-631 Air Quality Engineering

Fall: 12 units
The course provides a quantitative introduction to the processes that control atmospheric pollutants and the use of mass balance models to predict pollutant concentrations. We survey major processes including emission rates, atmospheric dispersion, chemistry, and deposition. The course includes discussion of basic atmospheric science and meteorology to support understanding air pollution behavior. Concepts in this area include vertical structure of the atmosphere, atmospheric general circulation, atmospheric stability, and boundary layer turbulence. The course also discusses briefly the negative impacts of air pollution on society and the regulatory framework for controlling pollution in the United States. The principles taught are applicable to a wide variety of air pollutants but special focus is given to tropospheric ozone and particulate matter. The course is intended for graduate students as well as advanced undergraduates. It assumes a knowledge of mass balances, fluid mechanics, chemistry, and statistics typical of an undergraduate engineer but is open to students from other scientific disciplines.
Prerequisites: 36-220 and 24-231 and 09-105

06-634 Drug Delivery Systems

Fall and Spring: 9 units
The body is remarkable in its ability to sequester and clear foreign entities - whether they be "bad" (e.g. pathogens) or "good" (e.g. therapeutic drugs). This course will explore the design principles being used to engineer modern drug delivery systems capable of overcoming the body's innate defenses to achieve therapeutic effect. Specifically, we will study the chemistry, formulation, and mechanisms of systems designed to deliver nucleic acids, chemotherapeutics, and proteins across a variety of physiological barriers. Scientific communication plays a prominent role in the course, and students will have several opportunities to strengthen their communication skills through journal club presentations, proposal writing and constructive feedback. This is a graduate level course that is also open to undergraduate seniors.

06-642 Data Science and Machine Learning in Chemical Engineering

Fall and Spring: 6 units
This class will examine topics related to data science and machine learning in chemical engineering. This includes topics in data visualization and modeling. The course will emphasize computational implementations of these topics with applications in chemical engineering. Students will need to be comfortable with scientific programming. Students who have taken 06-623 and/or 06-625 should have the skills needed in this class.

06-643 Creating Scientific Research Software

Fall and Spring: 6 units
This course will introduce students to topics in creating scientific research software. This will include using a shell, creating and using command-line utilities, using software editors, using version control systems, and creating and distributing software packages for scientific research.

06-663 Analysis and Modeling of Transport Phenomena

Spring: 12 units
Students will learn the basic differential equations and boundary conditions governing momentum, heat, and mass transfer. Students will learn how to think about these equations in dimensionless terms and will apply them to model physical and chemical processes. The primary mode for solving them will be numerical. Analytical results for classical problems of high symmetry also will be presented to serve as a basis for comparison and validation. Software: A finite element and computational transport tool.

06-665 Process Systems Modeling

Spring: 12 units
Simulation and optimization of complex flowsheets, synthesis of separation systems, planning and enterprise-wide optimization, process control and molecular design. Primary Software Package(s): Process Simulation software. Target Audience: first year masters students in chemical engineering Prerequisite skills: analytical and mathematical skills typical of an undergraduate engineering degree or technical degree.

06-679 Introduction to Meteorology

Fall and Spring: 12 units
Provide you with the basics of meteorology, with a focus on large-scale atmospheric motion. By the end of the class you will understand the basics of atmospheric dynamics, including horizontal and vertical motion, as well as the vertical structure of the atmosphere (atmospheric stability and boundary-layer dynamics). You will understand what makes weather happen and you will understand weather maps and charts. You will be able to critically watch the nightly weather forecast and you will be able to access available meteorological databases to make informed predictions of your own. Finally, you will understand atmospheric transport and boundary-layer dynamics, which will serve as a foundation for other coursework involving atmospheric transport and air-pollution if you are pursuing those topics more deeply.

06-685 Bioseparations and Bioprocess Analytical Technologies

Spring: 12 units
This course gives an introduction to key principles of bioseparations and process analytical technologies relevant to the manufacture of biopharmaceuticals. Transport modeling principles are applied to sedimentation/centrifugation, flocculation, and filtration of antibodies and plasmid DNA from raw cell culture. Polishing methods such as Protein A chromatography and size-exclusion chromatography are a particular focus. Chemical means to graft affinity ligands to commercial media are discussed along with in-line spectroscopic techniques. A molecular-level basis of light absorbance and fluorescence is established and the selection and conjugation of fluorophores to biomolecules of interest is presented. Means to assess the state of antibody aggregation and the proper folding of protein-based therapeutics are covered in the context of spectroscopic identification. Finally, the course will provide an overview of the diverse metrics needed for analysis of biomacromolecules as well as the variety of techniques used to analyze quality of produced materials by comparing cost, speed, accuracy and precision.

06-686 ST: Polymers for a Sustainable Future

Fall and Spring: 9 units
This course presents basic concepts of polymer science and discusses topics related to polymers and sustainability. Condensation, radical, ionic, emulsion, and ring-opening polymerizations, polymer behavior in solution and in the bulk will be explored in relation to material applications. We will touch on topics including chemistry of biomass and sustainable utilization of bio-based materials, along with polymers for sustainable technologies in renewable energy, water, and the environment.

06-702 Advanced Reaction Kinetics

Spring: 12 units
Advanced application of engineering and scientific principles to the study of complex chemical reaction systems. Catalytic and noncatalytic reactions in homogeneous and heterogeneous systems, fast reaction techniques, and isothermal and non-isothermal reaction design.

06-705 Advanced Chemical Engineering Thermodynamics

Fall: 12 units
Advanced application of the general thermodynamic method to chemical engineering problems. Second law consequences, estimation and correlation of thermodynamic properties, and chemical and phase equilibria.

06-707 Advanced Transport Phenomena

Fall and Spring: 12 units
An introduction to foundational concepts in mass, momentum, and energy transport. The governing equations for such transport phenomena in flowing fluids will be derived and then analyzed in a variety of scenarios, including unidirectional flows, lubrication theory, Stokes flow, and forced convection heat and mass transfer. The focus will be on problem formulation and solution using applied mathematical techniques. Throughout, the importance of developing a physical intuition for transport phenomena will be emphasized.

06-713 Mathematical Techniques in Chemical Engineering

Fall: 12 units
Selection, construction, solution, and interpretation of mathematical models applicable to the study of chemical engineering problems. Mathematical topics emphasized include divergence, curl and gradient operators, vector field theory, the solution of ordinary and partial differential equations by infinite series, separation of variables, Green's functions, regular and singular perturbations, and boundary-layer techniques.

06-714 Surfaces and Adsorption

Fall and Spring: 12 units
A survey of solid surfaces and gas-solid interactions. Topics include the structure and electronic properties of metal surfaces, the kinetics and thermodynamics of adsorption and desorption processes, and concepts in heterogeneous catalysis. The course emphasizes the application of recent experimental techniques in studying these problems.

06-722 Bioprocess Design

Fall and Spring: 12 units
This course is designed to link concepts of cell culture, bioseparations, formulation, and delivery together for the commercial production and use of biologically-based pharmaceuticals; products considered include proteins, nucleic acids, and fermentation-derived fine chemicals. Associated regulatory issues and biotech industry case studies are also included. A fair knowledge of cell culture and fermentation operations is assumed.

Department of Civil and Environmental Engineering

Burcu Akinci, Head
Location: Porter Hall 119-D
www.cmu.edu/cee (http://www.cmu.edu/cee/)

The role of civil and environmental engineers, in the broadest sense, is to apply science and technology to develop sustainable solutions to meet society's needs. Civil and environmental engineers plan, design, construct, operate, and maintain infrastructure used daily by the public and industry, such as buildings, transportation networks, water systems, and energy distribution systems. Civil and environmental engineers are at the forefront of technological developments to address the biggest societal challenges. They work to protect public health and the environment. Today's civil and environmental engineers are also called upon by government and industry to provide leadership on complex technical and societal issues such as demands for infrastructure improvement, remediation of former industrial sites for reuse, renewable energy, climate change adaptation, provision of safe drinking water, smart transportation systems, and sustainable development.

The department offers undergraduate degree programs leading to a B.S. in Civil Engineering or a B.S. in Environmental Engineering. The B.S. in Civil Engineering provides a broad exposure to the field and its sub-disciplines, including environmental engineering. The B.S. in Environmental Engineering offers the opportunity to focus primarily on environmental sciences and engineering. The two programs share a number of common courses.

The Civil Engineering and Environmental Engineering curricula emphasize fundamental understanding of the behavior of constructed facilities and the natural environment and the design of infrastructure through the application of the physical sciences, chemistry, biology, mathematics, and computing. In addition to providing a solid technical foundation, the programs emphasize the development of professional skills. We incorporate design and team experiences throughout the curriculum, and provide hands-on experience in laboratory and project courses. Students also have multiple opportunities to practice and improve their communication skills through reports, presentations, and team activities.

The curricula allow many opportunities for students to pursue areas of personal interest. Students may pursue a minor in one of the designated minor programs offered in the College of Engineering or elsewhere in the university or an additional major. Students may also choose to concentrate in a specialty area in civil or environmental engineering. Students are encouraged to participate in research with department faculty members, explore their chosen field through internships, and take advantage of opportunities to study abroad and be exposed to other cultures. Faculty mentors and the Director of Undergraduate Programs are available to discuss students' educational goals and help define a path to reach them.

The Department of Civil and Environmental Engineering offers a wide spectrum of opportunities for entry into the engineering profession, for graduate education in engineering, or entry into various other graduate and professional fields, including business, law, and medicine. Our curricula emphasize the development of scientific inquiry in the context of applications in civil and environmental engineering. For B.S. graduates who wish to enter the engineering profession directly in such specialties as structural engineering, construction engineering, computer-aided engineering, or environmental engineering, this approach to teaching allows application of the most advanced technological developments. Those who wish to pursue graduate study are prepared to engage in research on the highest level, either in traditional specialties or in emerging fields such as smart infrastructure, climate change adaptation, and micromechanics.

Program Educational Objectives: B.S. Civil Engineering

The Program Educational Objectives are broad statements that describe what graduates are expected to attain within a few years of graduation. The objectives of the Bachelor of Science in Civil Engineering program are to develop graduates who embody the following definitions:

- Graduates distinguish themselves within their organizations as individuals able to provide sustainable solutions to a wide range of conventional, cutting-edge, and emerging professional challenges related to one or more of the areas of the built, natural, and information environments.
- Graduates are innovative, proactive, and adaptive professionals, highly engaged in their professional communities; graduates are prepared to take on leadership positions within their organizations and communities.
- Graduates are able to contribute and collaborate on developing sustainable solutions to local and global problems; graduates are able to cross geographic, cultural, and traditional discipline boundaries in developing solutions; graduates are able to develop just and equitable solutions.

The Bachelor of Science in Civil Engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org under the commission’s General Criteria and Program Criteria for Civil and Similarly Named Engineering Programs.

By the end of the B.S. program, students should have achieved the following student outcomes:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

3. an ability to communicate effectively with a range of audiences

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

The curriculum has been designed, and is periodically evaluated and refined, to provide students instruction and experiences that lead to the development of these abilities and skills.

Program Educational Objectives: B.S. Environmental Engineering

The Program Educational Objectives are broad statements that describe what graduates are expected to attain within a few years of graduation. The objectives of the Bachelor of Science in Environmental Engineering program are to develop graduates who embody the following definitions:

- Graduates distinguish themselves within their organizations as individuals able to provide sustainable solutions to a wide range of conventional, cutting-edge, and emerging professional challenges related to one or more of the areas of the built, natural, and information environments.
- Graduates are innovative, proactive, and adaptive professionals, highly engaged in their professional communities; graduates are prepared to take on leadership positions within their organizations and communities.
- Graduates are able to contribute and collaborate on developing sustainable solutions to local and global problems; graduates are able to cross geographic, cultural, and traditional discipline boundaries in developing solutions; graduates are able to develop just and equitable solutions.

By the end of the B.S. program, students should have achieved the following student outcomes:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

3. an ability to communicate effectively with a range of audiences

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

The Bachelor of Science in Environmental Engineering completed its first cycle of graduating students in May 2024 and will be formally evaluated by ABET in the fall of 2024. The program was designed in accordance with ABET general and program criteria. Accreditation would be applicable retroactively to the May 2024 graduates.

Curriculum: B.S. Civil Engineering

Minimum units required for B.S. in Civil Engineering 384

Students entering the College of Engineering declare a major near the end of the first year. First-year students take two introductory engineering courses as well as some restricted technical electives within the common foundation specified for first-year engineering students. By the end of the sophomore year, a Civil Engineering major is expected to have completed the Restricted Technical Electives in the following list and 12-100 Exploring CEE: Infrastructure and Environment in a Changing World.

Restricted Technical Electives		Units
09-101	Introduction to Experimental Chemistry	3
09-105	Introduction to Modern Chemistry I	10
or 09-111	Nanolegos: Chemical Building Blocks	
15-110	Principles of Computing	10
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-259	Calculus in Three Dimensions	9
or 21-254	Linear Algebra and Vector Calculus for Engineers	
21-260	Differential Equations	9
33-141	Physics I for Engineering Students	12
33-142	Physics II for Engineering and Physics Students	12

Notes on Math Requirements

1. All mathematics (21-xxx) courses required for the engineering degree taken at Carnegie Mellon must have a minimum grade of C in order to be counted toward the graduation requirement for the BS engineering degree.
2. A minimum grade of C must be achieved in any required mathematics (21-xxx) course that is a pre-requisite for the next higher level required mathematics (21-xxx) course.

Sample Curriculum

This section shows the recommended four-year program of study for the BS in Civil Engineering following a typical path. The curriculum for transfer students, students with advanced placement credit, and students planning to study abroad will not follow the same path. Students need to consult the department for appropriate advising and formulation of a plan to complete the degree within eight semesters.

First Year

Fall		Units
12-100	Exploring CEE: Infrastructure and Environment in a Changing World	12
21-120	Differential and Integral Calculus	10
33-141	Physics I for Engineering Students	12
99-101	Core@CMU	3
xx-xxx	General Education Course	9
		46

Spring		Units
xx-xxx	Introduction to Engineering (other than CEE)	12
21-122	Integration and Approximation	10
33-142	Physics II for Engineering and Physics Students	12
09-101	Introduction to Experimental Chemistry	3
xx-xxx	General Education Course	9
		46

Sophomore Year

Fall		Units
12-200	CEE Challenges: Design in a Changing World	9
12-212	Statics	9
12-233	CEE Infrastructure Systems in Action	2
21-259	Calculus in Three Dimensions	9
or 21-254	Linear Algebra and Vector Calculus for Engineers	
15-110	Principles of Computing	10
xx-xxx	General Education Course	9
39-210	Experiential Learning I	0
		48

Spring		Units
12-231	Solid Mechanics	9
12-234	Sensing and Data Acquisition for Engineering Systems	4
12-271	Computation and Data Science for Civil & Environmental Engineering	9
21-260	Differential Equations	9
36-220	Engineering Statistics and Quality Control	9
xx-xxx	General Education Course	9
39-220	Experiential Learning II	0
		49

Junior Year

Fall		Units
12-301	CEE Projects: Integrating the Built, Natural and Information Environments	9
12-335	Soil Mechanics	9
12-355	Fluid Mechanics	9
12-356	Fluid Mechanics Lab	2
09-111	Nanolegos: Chemical Building Blocks	9
or 09-105	Introduction to Modern Chemistry I	
xx-xxx	Elective 1	9
39-310	Experiential Learning III	0
		47

Spring		Units
12-351	Environmental Engineering	9
27-357	Introduction to Materials Selection	6
12-371	Advanced Computing and Problem Solving in Civil and Environmental Engineering	9
12-333	Experimental & Sensing Systems Design and Computation for Infrastructure Systems	4
xx-xxx	Elective 2	9
xx-xxx	General Education Course	9
		46

Senior Year

Fall		Units
12-401	CEE Design	12
12-411	Project Management for Engineering and Construction	9
xx-xxx	Elective 3	9
xx-xxx	Elective 4	9
xx-xxx	General Education Course	9
		48

Spring		Units
xx-xxx	General Education Course	9
xx-xxx	General Education Course	9

xx-xxx	Elective 5	9
xx-xxx	Elective 6	9
xx-xxx	Elective 7	9
xx-xxx	Elective 8	9
		54

Notes on Electives

1. One elective must be in the basic sciences, from the following list:

03-121	Modern Biology	9
12-201	Geology	9
12-353	Environmental Biology and Ecology	9
Substitutions may be made only with the approval of the Department Head.		

2. One elective course is restricted to a 600-level or 700-level Civil Engineering course of at least 9 units, except 12-648 and 12-690. The combination of 12-644 and 12-645 may also be used, but no other combination is allowed.
3. **Students are encouraged to take multiple 12-6xx and 12-7xx courses to provide them with specific civil engineering domain depth in their field(s) of interest.**

Curriculum: B.S. Environmental Engineering

Minimum units required for B.S. in Environmental Engineering 384

Students entering the College of Engineering declare a major near the end of the first year. First-year students take two introductory engineering courses as well as some restricted technical electives within the common foundation specified for first-year engineering students. By the end of the sophomore year, an Environmental Engineering major is expected to have completed the Restricted Technical Electives in the following list and 12-100 Exploring CEE: Infrastructure and Environment in a Changing World.

09-105	Introduction to Modern Chemistry I	10
or 09-111	Nanolegos: Chemical Building Blocks	
15-110	Principles of Computing	10
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-254	Linear Algebra and Vector Calculus for Engineers	11
21-260	Differential Equations	9
33-141	Physics I for Engineering Students	12
33-142	Physics II for Engineering and Physics Students	12

Notes on Math Requirements

1. All mathematics (21-xxx) courses required for the engineering degree taken at Carnegie Mellon must have a minimum grade of C in order to be counted toward the graduation requirement for the BS engineering degree.
2. A minimum grade of C must be achieved in any required mathematics (21-xxx) course that is a pre-requisite for the next higher level required mathematics (21-xxx) course.

SAMPLE CURRICULUM

This section shows the recommended four-year program of study for the BS in Environmental Engineering following a typical path. The curriculum for transfer students, students with advanced placement credit, and students planning to study abroad will not follow the same path. Students need to consult the department for appropriate advising and formulation of a plan to complete the degree within eight semesters.

First Year

Fall		Units
12-100	Exploring CEE: Infrastructure and Environment in a Changing World	12
21-120	Differential and Integral Calculus	10
33-141	Physics I for Engineering Students	12
99-101	Core@CMU	3
xx-xxx	General Education Course	9
		46

Spring		Units
xx-xxx	Introduction to Engineering (other than CEE)	12
21-122	Integration and Approximation	10
33-142	Physics II for Engineering and Physics Students	12
09-105	Introduction to Modern Chemistry I	10
or 09-111	Nanolegos: Chemical Building Blocks	
09-101	Introduction to Experimental Chemistry	3
		47

Sophomore Year

Fall		Units
12-200	CEE Challenges: Design in a Changing World	9
12-221	Environmental Chemistry and Thermodynamics	9
12-222	Environmental Chemistry Laboratory	3
15-110	Principles of Computing	10
21-254	Linear Algebra and Vector Calculus for Engineers	11
39-210	Experiential Learning I	0
xx-xxx	General Education Course	9
		51

Spring		Units
12-271	Computation and Data Science for Civil & Environmental Engineering	9
12-351	Environmental Engineering	9
12-352	Environmental Engineering Lab	3
21-260	Differential Equations	9
39-220	Experiential Learning II	0
xx-xxx	General Education Course	9
xx-xxx	Elective 1	9
		48

Junior Year

Fall		Units
12-301	CEE Projects: Integrating the Built, Natural and Information Environments	9
12-355	Fluid Mechanics	9
12-356	Fluid Mechanics Lab Starting in Fall 2022, 12-356 will be 2 units	2
03-121	Modern Biology	9
36-220	Engineering Statistics and Quality Control	9
39-310	Experiential Learning III	0
xx-xxx	General Education Course	9
		47

Spring		Units
12-353	Environmental Biology and Ecology	9
12-371	Advanced Computing and Problem Solving in Civil and Environmental Engineering	9
12-201	Geology	9
xx-xxx	Elective 2	6
xx-xxx	Elective 3	9
xx-xxx	General Education Course	9
		51

Senior Year

Fall		Units
12-401	CEE Design	12
12-411	Project Management for Engineering and Construction	9
xx-xxx	General Education Course	9
xx-xxx	General Education Course	9
xx-xxx	General Education Course	9
		48

Spring		Units
12-451	Advanced Environmental Engineering	9
12-471	Applied Data Analytics for Civil and Environmental Systems	9
xx-xxx	Upper Level Environmental Engineering Elective	9
xx-xxx	Elective 4	9
xx-xxx	Elective 5	9
		45

Notes on Electives

1. **Students are encouraged to take multiple upper level courses to provide them with specific environmental engineering domain depth in their field(s) of interest.**

Specialty Areas in Civil Engineering

Students may select a set of civil engineering and other electives in the junior and senior years that enable them to concentrate in a specialty area, if they so desire. Some examples for grouping electives into specialty areas, together with representative course selections, are indicated below. Students can define other specialty area concentrations; discussion with a faculty mentor is encouraged. Specialty areas are not noted on the official transcript.

STRUCTURAL ENGINEERING

		Units
12-201	Geology	9
12-631	Structural Design	12
12-635	Structural Analysis	12
12-636	Geotechnical Engineering	9
21-241	Matrices and Linear Transformations	10
24-311	Numerical Methods	12
24-351	Dynamics	10

Computing in Civil Engineering

		Units
12-600	AutoCAD	3

12-623	Molecular Simulation of Materials	12
12-645	Smart Cities: Growth and Intelligent Transportation Systems	6
12-659	Special Topics: Matlab	6
24-451	Feedback Control Systems	12
24-650	Applied Finite Element Analysis	12
24-658	Image-Based Computational Modeling and Analysis	12

engineering and society

		Units
12-645	Smart Cities: Growth and Intelligent Transportation Systems	6
12-657	Water Resource Systems Engineering	9
24-291	Environmental Systems on a Changing Planet	9
48-371	City & Suburb: Housing in America after 1850	9
79-303	Pittsburgh and the Transformation of Modern Urban America	6
79-315	The Politics of Water in Global Perspective	9

Construction Management

		Units
12-600	AutoCAD	3
12-631	Structural Design	12
12-635	Structural Analysis	12
12-636	Geotechnical Engineering	9
48-380	Constructing Value(s): Economies of Design	6
70-311	Organizational Behavior	9
70-321	Negotiation and Conflict Resolution	9

NEXT-GENERATION BUILDING AND CONSTRUCTION

		Units
12-631	Structural Design	12
39-245	Rapid Prototype Design	9
48-530	Human-Machine Virtuosity	12
48-555	Introduction to Architectural Robotics	9

SMART CITIES

		Units
12-600	AutoCAD	3
12-612	Intro to Sustainable Engineering	9
12-631	Structural Design	12
12-635	Structural Analysis	12
12-636	Geotechnical Engineering	9
12-644	Intro to Transportation Systems Analysis	6
12-645	Smart Cities: Growth and Intelligent Transportation Systems	6
24-643	Energy Storage Materials and Systems	12

SMART BUILDINGS

12-600	AutoCAD	3
12-631	Structural Design	12
12-635	Structural Analysis	12
48-116	Introduction to Building Performance	9
48-315	Environmental Systems: Climate & Energy in Buildings	9
48-432	Environment II: Design Integration of Active Building Systems	9

MATERIALS

		Units
12-623	Molecular Simulation of Materials	12
24-643	Energy Storage Materials and Systems	12
27-201	Structure of Materials	9
27-202	Defects in Materials	9
27-215	Thermodynamics of Materials	12
27-301	Microstructure and Properties I	9
27-406	Sustainable Materials	9
27-503	Additive Manufacturing and Materials	9

Specialty Areas in Environmental Engineering

ENVIRONMENTAL ENGINEERING - WATER QUALITY

		Units
12-612	Intro to Sustainable Engineering	9
12-657	Water Resource Systems Engineering	9

ENGINEERING AND SOCIETY

		Units
12-645	Smart Cities: Growth and Intelligent Transportation Systems	6
12-657	Water Resource Systems Engineering	9
24-291	Environmental Systems on a Changing Planet	9
48-371	City & Suburb: Housing in America after 1850	9
79-303	Pittsburgh and the Transformation of Modern Urban America	6
79-315	The Politics of Water in Global Perspective	9
19-429	Climate Change Science and Solutions	9

ENVIRONMENTAL ENGINEERING - ENERGY

		Units
12-612	Intro to Sustainable Engineering	9
24-424	Energy and the Environment	9
24-292	Renewable Energy Engineering	9
24-628	Energy Transport and Conversion at the Nanoscale	12

ENVIRONMENTAL ENGINEERING - AIR QUALITY

		Units
12-612	Intro to Sustainable Engineering	9
12-651	Air Quality Engineering	9
24-425	Combustion and Air Pollution Control	9
19-429	Climate Change Science and Solutions	9

Additional Majors and Minors

Civil Engineering and Environmental Engineering students may pursue additional majors and minors in a variety of subjects, taking advantage of the free elective courses to satisfy the requirements for the major or minor. The College of Engineering has designated minors to promote flexibility and diversity among engineering students. Many Civil Engineering and Environmental Engineering undergraduates pursue designated minors in areas such as Architecture, Environmental and Sustainability Studies, or Global Engineering.

Internships and Co-Operative Education Program

Students in Civil Engineering and Environmental Engineering are encouraged to undertake professional internships during summer breaks. In addition, a cooperative internship program is possible for either Jan-Aug or May-Dec in the junior year. Students undertaking these 8-month professional internships would ordinarily graduate after an additional semester of study.

Integrated B.S./M.S. Program

Interested undergraduates may plan a course of study that leads to either the B.S. in Civil Engineering or the B.S. in Environmental Engineering as well as the M.S. in Civil and Environmental Engineering. This course of study will ordinarily require ten semesters, although advanced placement or other study may reduce this time. In the ninth semester of study, students must register in graduate status. Interested students should consult the Director of Undergraduate Programs for information about admission to the M.S. program.

Faculty

AMIT ACHARYA, Professor of Civil and Environmental Engineering – Ph.D., University of Illinois at Urbana - Champaign; Carnegie Mellon, 2000–

PETER ADAMS, Thomas Lord Professor of Engineering, Civil and Environmental Engineering and Engineering and Public Policy; Department Head of Engineering and Public Policy – PhD., California Institute of Technology; Carnegie Mellon, 2001–

BURCU AKINCI, Department Head and Paul P. Christiano Professor of Civil and Environmental Engineering – Ph.D., Stanford University; Carnegie Mellon, 2000–

MARIO BERGES, Professor of Civil and Environmental Engineering – Ph.D., Carnegie Mellon Univesity; Carnegie Mellon, 2010–

JACOBO BIELAK, P.E., Hamerschlag University Professor Emeritus of Civil and Environmental Engineering – Ph.D., California Institute of Technology, , P.E.; Carnegie Mellon, 1978–

SARAH J. CHRISTIAN, P.E., Associate Teaching Professor of Civil and Environmental Engineering – Ph.D., Stanford; Carnegie Mellon, 2015–

KAUSHIK DAYAL, Professor of Civil and Environmental Engineering – Ph.D., California Institute of Technology; Carnegie Mellon, 2008–

DAVID A. DZOMBAK, P.E., Hamerschlag University Professor Emeritus of Civil and Environmental Engineering – Ph.D., Massachusetts Institute of Technology, P.E.; Carnegie Mellon, 1989–

SARAH FAKHREDDINE, Assistant Professor of Civil and Environmental Engineering – PhD, Stanford; Carnegie Mellon, 2022–

SUSAN FINGER, Professor of Civil and Environmental Engineering; Associate Dean, Integrative Design Arts & Technology (IDeATe) – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1989–

KATHERINE A. FLANIGAN, Assistant Professor of Civil and Environmental Engineering – PhD, University of Michigan; Carnegie Mellon, 2020–

JAMES H. GARRETT, JR. P.E., Provost – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1990–

KELVIN GREGORY, Professor and Executive Director of Undergraduate and Graduate Programs, Civil and Environmental Engineering – Ph.D., University of Iowa; Carnegie Mellon, 2006–

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GREGORY LOWRY, Walter J. Blenko, Sr. Professor of Civil and Environmental Engineering – Ph.D., Stanford University; Carnegie Mellon, 2002–

JOE MOORE, Assistant Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2017–

DESTENIE NOCK, Assistant Professor of Civil and Environmental Engineering and Engineering and Public Policy – PhD, University of Massachusetts, Amherst; Carnegie Mellon, 2019–

FETHIYE OZIS, P.E., Associate Teaching Professor of Civil and Environmental Engineering – PhD, University of Southern California; Carnegie Mellon, 2022–

MATTEO POZZI, Professor of Civil and Environmental Engineering – Ph.D., University of Trento, Italy; Carnegie Mellon, 2012–

ZHEN (SEAN) QIAN, Professor of Civil and Environmental Engineering – Ph.D., University of California, Davis; Carnegie Mellon, 2015–

DAVID ROUNCE, Assistant Professor of Civil and Environmental Engineering – PhD, University of Texas at Austin; Carnegie Mellon, 2020–

CONSTANTINE SAMARAS, Professor of Civil and Environmental Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2014–

MITCHELL J. SMALL, H. John Heinz Professor Emeritus of Civil and Environmental Engineering and Engineering and Public Policy – Ph.D., University of Michigan; Carnegie Mellon, 1982–

PINGBO TANG, Associate Professor of Civil and Environmental Engineering – PhD, Carnegie Mellon University; Carnegie Mellon, 2020–

JEANNE VANBRIESEN, P.E., Duquesne Light Company Professor of Civil and Environmental Engineering and Engineering and Public Policy; Vice Provost for Faculty – Ph.D., Northwestern University; Carnegie Mellon, 1999–

GERALD J. WANG, Assistant Professor of Civil and Environmental Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2019–

Department of Civil and Environmental Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

12-100 Exploring CEE: Infrastructure and Environment in a Changing World

Fall and Spring: 12 units
Civil and Environmental Engineers (CEEs) engage in the planning, design, construction, operation, retrofit, demolition, and reuse of large-scale infrastructure that forms the backbone of all societies and economies. CEEs work at the dynamic interface of the built environment, information environment, and natural environment. Therefore, societal domains that require CEE expertise include smart cities and construction, sustainable energy and buildings, connected and automated transportation systems, resilient infrastructure, climate change mitigation and adaptation, and water management. Students will explore how sensing, data science, environmental science, life cycle systems and economic analysis, and infrastructure design are integrated to create a built environment that meets the needs of smart and connected communities while enhancing sustainability. Students work on team-based design-build projects that introduce principles from environmental, structural, construction engineering, and project management. Students learn technical skills as well as methods for management and design considerations that include uncertainty, economics, and ethics, for modern and future infrastructure.

12-200 CEE Challenges: Design in a Changing World

Fall: 9 units
Building upon design themes introduced in 12-100, in this course, students will be challenged to solve more complex problems related to conventional, cutting-edge, and emerging issues in Civil and Environmental Engineering and one or more of the areas of the built, natural, and information environments, such as smart cities. Students will gain an understanding of the effects of uncertainty, such as changing climate conditions. Through several team projects, students will explore the impact and management of tradeoffs, like constructability, sustainability, cost, and maintenance on design. They will learn to apply mathematics and science, advanced technologies, and computing to solve open-ended problems. Students will learn communication, project management, and design skills and practice the design process, from problem definition to constructed work.
Prerequisite: 12-100

12-201 Geology

Fall and Spring: 9 units
Introduction to physical geology; common rocks and rock-forming minerals and their chemical compositions/structure, physical properties, origins, and uses; geologic processes: surface and ground-water flow, volcanism, mountain-building, tectonics, glaciation, sedimentation, seismicity, and atmospheric and oceanic circulation.

12-212 Statics

Fall: 9 units
Introduction to vector mechanics; equivalent systems of forces; equilibrium of rigid bodies; free body diagram; distributed forces, hydrostatic forces, effective forces, centroids; applications to simple statically determinate trusses, beams, frames, cables and other physical systems; friction.

12-215 Introduction to Professional Writing in CEE

Fall: 9 units
The objective of the course is to prepare students for writing technical reports and essays assigned in CEE courses and laboratories, writing professional letters and reports for internships and professional positions, preparing documents in a team setting, delivering individual and team oral presentations, and transforming information for several types of audiences (scientific accommodation). The course focuses on document purpose, organization and style; basic editing techniques; scientific accommodation; plagiarism and proper paraphrasing and summarizing; evaluating, citing and referencing sources; team communication strategies; oral presentations; and proper use of tables, graphics, and other visual aids in documents and presentations. Course activities include in-class exercises, peer workshops, and homework assignments to illustrate examples of good and poor communication and to practice technical communication skills. Concurrent with lectures and class activities, students draft and revise individual and team technical reports and will give individual and team oral presentations.

12-221 Environmental Chemistry and Thermodynamics

Fall: 9 units
Environmental chemistry is foundational to the understanding of processes in natural and engineered systems. This course introduces environmental chemistry principles within the context of air and water systems. It focuses on the use of stoichiometry, thermodynamics, equilibrium, and kinetics to understand processes governing chemical and biological behaviors in natural and engineered systems. Topics in water include acid-base chemistry, the carbonate system, buffering, oxidation and reduction, mineral dissolution/precipitation, metal complexation, adsorption, and partitioning. Topics in air and climate to be discussed include atmospheric chemistry, air quality, combustion, aerosols, and climate science.
Prerequisites: 09-105 or 09-111

12-222 Environmental Chemistry Laboratory

Fall: 3 units
Students learn to conduct lab and field experiments relevant to environmental engineering and the understanding of natural and engineered systems. Exercises involve the collection and analysis of data from major domains of the environment (air, water, soil, sediments). Students learn to use state-of- the-art environmental analytical techniques. Students develop collaborative skills through team-based laboratory exercises and practice skills in written communication of laboratory results.

12-231 Solid Mechanics

Spring: 9 units
Understanding and calculating the deformation and eventual failure of solids is fundamental to the design of structures and materials for civil engineering applications ranging from structural analysis and design of buildings and bridges to the design of novel materials and structures optimized for specific functionality. This course provides students with an introduction to fundamental concepts and methods in solid mechanics. Topics covered include stress, strain, mechanical properties of materials, and geometric compatibility; response under axial loads, torsion, bending, transverse shear, and combined loadings; stress transformations and Mohr's circles, deflections of beams and shafts, and buckling of columns. Students will develop problem solving skills and apply these concepts to analyze deformable bodies.
Prerequisite: 12-212

12-233 CEE Infrastructure Systems in Action

Fall: 2 units
Civil and environmental engineering infrastructure is all around us. CEE infrastructure is integral to society's day-to-day operations, providing, for example, shelter, transportation, and clean drinking water. In this course, students will get a first-hand experience of civil and environmental engineering in action all around us. The course is comprised of lab sessions during which students will learn about and investigate infrastructure and phenomena in the built and natural environments on or near campus. Student coursework includes short assignments and reflections related to the lab experience.
Prerequisite: 12-100

12-234 Sensing and Data Acquisition for Engineering Systems

Spring: 4 units
Collecting and analyzing massive amounts of data is integral to understanding and managing the complexities of our infrastructure systems. Civil and environmental engineers need to select tools and to collect data to gain an understanding of the problems they are trying to solve. In this course, students will learn how to choose and use a range of measuring tools from simple hand tools to advanced sensors to collect data in laboratory-based and system-level studies, followed by data acquisition and processing. Experiment subjects will span the breadth of the fields including, for example, structural, geotechnical, environmental, and transportation engineering. The sensors and data will be used to assess not only an individual infrastructure component, but also infrastructure systems and networks. Students will complete planning activities for each of the experiments, conduct experiments, and acquire the resulting data from sensors and other measurements. Results and analysis will be submitted as part of a report or post-laboratory assignment.
Prerequisite: 12-212

12-271 Computation and Data Science for Civil & Environmental Engineering

Spring: 9 units
Computational science and computer applications play an important role in modern engineering practice and research. This course provides students with an introduction to the fundamentals of computation and data science using both deterministic and stochastic techniques. Topics include numerical methods for approximation, differentiation, integration, Monte Carlo simulation, quantifying error and uncertainty, regression, solving linear systems of equations and ordinary differential equations, root finding, and optimization; the use of several computing paradigms (numerical, symbolic, and spreadsheet) for enhancing engineering workflows with modeling and data, with an emphasis on identifying the appropriate tool for various engineering problems; the importance of and approaches for effective visual presentation of data; and the future of computer-based methods in engineering. Mathematical concepts from calculus, probability, and linear algebra are introduced as needed. Through application of these principles, students will develop the computational reasoning skills that are required to design and deploy computer-based solutions for a variety of problems in civil and environmental engineering.
Prerequisites: 21-120 Min. grade C and 33-141 and (15-110 or 15-112) and 21-122 Min. grade C

12-301 CEE Projects: Integrating the Built, Natural and Information Environments

Fall: 9 units
Civil and environmental engineers work at the interface of multiple disciplines, understanding and applying principles to evaluate and create. This course extends design skills from 12-100 and 12-200 to hands-on experiences with more integrated, interdisciplinary problem solving. Students explore the roles of diverse stakeholders, community engagement, and sustainability goals in CEE projects. Students integrate construction/structures, sensing, and sustainability through team-based projects, and apply communication, computation, and project management skills. Students develop an understanding of the professional, ethical, social, and economic aspects of engineering projects. The course combines formal instruction, field trips, teamwork, role-playing, and engagement with practicing experts involved with CEE projects.
Prerequisites: 12-271 and 12-200

12-333 Experimental & Sensing Systems Design and Computation for Infrastructure Systems

Spring: 4 units
Civil and environmental engineers must decide what information they need to collect, how to collect it, how to analyze the data and how to use that data to develop solutions for a changing world. Data are often incorporated into computational models to gain further insight and understanding of the problem and potential solutions. In this course, students will learn and develop different approaches to solve problems like field testing, laboratory experimentation, computer simulation, and data analytics. Students will design their own testing protocols and develop computer models to simulate situations that are difficult or expensive to sense in the real-world. Pre- and post-laboratory assignments or reports will be completed to document plans and to present an analysis of results.
Prerequisite: 12-356

12-335 Soil Mechanics

Fall: 9 units
Understanding the behavior of soils is essential for many applications within civil and environmental engineering from construction safety and structural integrity of buildings, to foundations, levees, groundwater remediation, landfill design, and erosion control. This course provides students with an introduction to fundamental concepts and methods in soil mechanics and geotechnical engineering. Topics covered in the course include physical, chemical and hydraulic characteristics and mineral composition of soils; stress-strain-strength relationships; permeability; consolidation; shear strength; and lateral earth pressure. Students will apply knowledge of these fundamentals to solve civil and environmental engineering problems related to soil deformation, stability, and groundwater flow.
Prerequisites: 12-231 and 33-142

12-351 Environmental Engineering

Spring: 9 units
Environmental engineering applies sustainability science, engineering principles, and systems approaches to protect the environment and human health. This includes protecting natural ecosystems and enhancing the quality of human life through environment-related policy development and technological innovation, and assessing the environmental impacts or benefits of infrastructure projects. This course provides a scientific and engineering basis for understanding and developing sustainable solutions for challenges in environmental and public health protection, especially in relation to urban water systems, with links to energy and climate. Topics covered include: sustainability; basic principles of water chemistry and microbiology; mass and energy balances; reactor theory and models; physical-chemical and biological processes; drinking water treatment; wastewater treatment; rivers, lakes, and ecosystems. Students will develop quantitative problem-solving skills for environmental engineering challenges. Students will also learn about and analyze current environmental and public health issues.
Prerequisites: 09-105 or 09-111

12-352 Environmental Engineering Lab

Spring: 3 units
Environmental engineering depends on many kinds of measurements as well as experimentation for monitoring and managing natural and engineered systems. In this course, students will design and conduct laboratory experiments that illustrate the fundamental principles of chemical, physical, and biological processes learned in environmental engineering. Topics include acid-base chemistry, carbonate chemistry, solids removal, and pathogen detection. Experiments include applications of methods to detect and quantify both inorganic and organic contaminants in water, and methods to remove contaminants from water. Students will also advance teamwork skills through group efforts and collaborative writing.

12-353 Environmental Biology and Ecology

Spring: 9 units
Profound changes are affecting our environment, including climate change, habitat loss, pollution, and invasive species. Understanding ecosystems and their inhabitants and functions is critical to engineering a sustainable future for humans. This course is an introduction to ecology and biology for environmental engineers. Ecology topics include the relationships among organisms and between organisms and their environment; and adaptations, populations, communities, and terrestrial and aquatic ecosystems.
Biology subjects will focus on microbiology, as bacteria are an analog for more-complex species. Microbiology topics include biological molecules, biochemical reactions, energetics, diversity of microbial metabolism, physiology, biofilms, biogeochemical cycles, and the degradation of pollutants.
Prerequisite: 03-121

12-355 Fluid Mechanics

Fall: 9 units
The flow of fluids is important in many civil and environmental engineering applications ranging from water infrastructure and coastal engineering to bridge design. This course provides students with an introduction to fundamental concepts and methods in fluid mechanics. Topics covered in the course include fluid properties; pressure, hydrostatics, and buoyancy; open systems and control volume analysis; conservation of mass and momentum for moving fluids; viscous fluid flows and flow in conduits; dimensional analysis and similitude; open channel flows; lift and drag on immersed bodies; and differential analysis. Through application of these concepts, students will develop problem-solving skills and formulate models necessary to study, analyze, and design fluid systems essential to good engineering practice of fluid mechanics. Civil Engineering undergraduates register for section A. Environmental Engineering undergraduates register for section B. All graduate students register for section C.
Prerequisite: 21-260 Min. grade C

12-356 Fluid Mechanics Lab

Fall: 2 units
An understanding of fluid mechanics is greatly enhanced by hands-on experimentation and experience with the physical concepts of fluid flows. In this course, students will develop an ability to conduct experiments, take measurements, and analyze and interpret data in fluid mechanics. Topics covered include measurement of fluid properties; static forces on immersed surfaces; continuity and energy; viscous pipe flow; and open channel flow. Students will foster teamwork skills and an ability to creatively develop independent ideas around the description of fluid mechanics through small-group work with experimental apparatus and individual reports on the acquired data.

12-371 Advanced Computing and Problem Solving in Civil and Environmental Engineering

Spring: 9 units
Building upon the fundamentals developed in 12-271, this course introduces students to advanced topics in computational problem solving that are critical for implementing and interpreting computational solutions in civil and environmental engineering practice. These topics include numerical methods (both deterministic and stochastic) for approximation, differentiation, and integration in high dimensions; topics in numerical linear algebra for data science (including applications of QR factorization, singular-value decomposition, and Cholesky factorization); an introduction to clustering, regression, and classification; an introduction to statistical sampling; an introduction to graph and network theory; topics in deterministic and stochastic optimization; an introduction to scripting and automation; numerical solutions of ordinary differential equations (including finite differences and basic finite-element analysis); and practices for effective visualization of large data sets. Each topic is presented with real-world civil and environmental engineering problems, in areas such as smart cities, transportation, energy, buildings, and hydrology. An emphasis is placed on identifying the appropriate computational method for any specific problem; additional emphasis is placed on developing computational thinking. This course culminates in a project, which requires students to synthesize their computational reasoning skills in order to solve a challenging civil and environmental engineering problem.
Prerequisite: 12-271

12-401 CEE Design

Fall: 12 units
This capstone design experience integrates knowledge and experience from technical and professional skills acquired in the civil engineering and environmental engineering project course sequence. Students apply the design process and knowledge from the core curriculum to design engineering solutions to real engineering problems. Students work in teams in a pre-professional environment to meet the challenges with which they are presented. Oral, written, and graphic communications both within teams and with external audiences are essential to successful completion of the projects. Students manage the design process as they work with community partners to co-design solutions during the semester-long project. Student teams work with community partners to define the engineering problem, including requirements and performance criteria, and to imagine and evaluate potential solutions. Teams produce models and calculations to assess performance with respect to requirements and performance criteria and detailed design deliverables to convey the recommended solution.
Prerequisite: 12-301

12-411 Project Management for Engineering and Construction

Fall: 9 units
Through planning and management, and optimization and allocation of materials and labor under time and financial constraints, project managers lead teams to achieve project goals. This course is an introduction to project management of engineering, construction, and operations of building facilities and civil infrastructure. This course emphasizes design, construction, and operation as an integrated process and examines various topics related to four core aspects of project management - time, cost, quality, and safety. Engineering and management cases from civil, construction, and infrastructure engineering domains will be examined. Topics covered include contracting issues, legal structures, project planning and scheduling, cash flows, cost estimation and financing of constructed facilities, labor productivity, material management, equipment utilization, cost control, monitoring, and accounting for construction. The course will introduce various software tools useful for implementation of these topics, including project scheduling and management tools, software for optimization and economic analysis, field operation analysis tools, and digital design and modeling tools. Civil engineering undergraduates register for section A. Environmental Engineering undergraduates register for section B. All graduate students register for section C.
Prerequisite: 12-301

12-451 Advanced Environmental Engineering

Spring: 9 units
Building on fundamental concepts from 12-221, 12-351, and 12-353, this course focuses on the physical, chemical, and biological processes controlling the quality of water, soil, air and #8212; and ultimately human and ecosystem health. Students will learn how these processes regulate the cycling of contaminants and nutrients in the environment. Key topics include material and energy balances, advective-dispersive transport with reacting solutes, and partitioning of contaminants and nutrients across different media. Students will also gain familiarity with (1) how regulatory agencies and decision-makers account for these processes in environmental protection efforts and (2) related challenges and opportunities around climate change.
Prerequisites: 12-355 and 12-353 and 12-351 and 12-221

12-471 Applied Data Analytics for Civil and Environmental Systems

Spring: 9 units
Building upon the fundamentals developed in 12-271 and 12-371, this course empowers students to leverage computing tools for big data. Topics include design of experiments; advanced topics in statistics and uncertainty quantification; an introduction to signal processing and Fourier theory; an introduction to classification, clustering, and other concepts from machine learning; and an introduction to parallel and distributed computing and sensing. Each topic is presented in the context of a specific set of engineering problems. An emphasis is placed on identifying computationally appropriate and efficient solutions. This course culminates in a collaborative project, enabling students to synthesize their computational and data science skills to solve a significant problem in civil and environmental systems
Prerequisite: 12-371

12-600 AutoCAD

Fall and Spring: 3 units
AutoCAD is mostly held online. The course provides an introduction to the fundamentals of computer-aided design (CAD)software. Students learn how to set up CAD projects using Autodesk's AutoCAD software. Topics include coordinates, lines, circles, arcs, zooms, snaps and grids, text, views, layers, plines, blocks, reference files, dimensioning, isometrics, 3D commands, surfaces, solids, and more. CAD standards for layers, plotting, and symbol libraries are also covered. The course includes development of a CAD project by each student.

12-612 Intro to Sustainable Engineering

Fall: 9 units
This course presents an overview of the concept of sustainability, including changing attitudes and values toward technology and the environment through the late twentieth and early twenty-first centuries. Relevant issues in sustainable engineering, including population growth, urbanization, energy, water, food and material resources are discussed. Tools for sustainable engineering are presented, including metrics of sustainability, principles of design for the environment, and use of material and energy balances in sustainable systems.

12-623 Molecular Simulation of Materials

Spring: 12 units
The purpose of this course is to expose engineering students to the theory and implementation of numerical techniques for modeling atomic-level behavior. The main focus is on molecular dynamics and Monte Carlo simulations. Students will write their own simulation computer codes, and learn how to perform calculations in different thermodynamic ensembles. Consideration will be given to heat transfer, mass transfer, fluid mechanics, mechanics, and materials science applications. The course assumes some knowledge of thermodynamics and computer programming. 4 hrs lec.

12-631 Structural Design

Spring: 12 units
Design of structural members for bending moment, shear force, axial force, and combined axial force and bending. Reinforced concrete, structural steel, and composite beam construction are considered. Buckling effects in columns, beams and local plate segments are treated. Serviceability limits such as deflection and cracking are addressed. Design projects include the determination of loads and the selection of system geometry.
Prerequisite: 12-231

12-635 Structural Analysis

Fall: 12 units
Classical and matrix-based methods of structural analysis; energy principles in structural mechanics. Basic concepts of force and displacement methods for analyzing redundant structural systems. Matrix methods utilizing the flexibility (force) and stiffness (displacement) concepts.
Prerequisite: 12-231

12-636 Geotechnical Engineering

Spring: 9 units
Behavior of geotechnical structures; engineering design of geotechnical structures considering failure modes; uncertainties; economic issues, required design formats and relevant code provisions; performance requirements for foundations, subsurface investigations; allowable stress and LRFD design approaches; reliability-based design; shallow foundations; deep foundations; retaining structures; reinforced concrete foundations.
Prerequisite: 12-335

12-644 Intro to Transportation Systems Analysis

Fall: 6 units
This course covers fundamentals of planning, design, and operation of roadway transportation. Topics covered include basic traffic flow theory, traffic signal design and evaluation, transportation planning, pricing of transportation systems, and basic data analytics techniques. It also teaches the basics of the travel behavior model to understand planning of public transit services. The objective is to develop the capability to: 1) understand the principles of transportation planning, transportation economics and system management; 2) analyze transportation systems with emerging mobility data; and 3) apply methodologies to solve transportation system problems and develop management strategies/policies.

12-645 Smart Cities: Growth and Intelligent Transportation Systems

Fall: 6 units
Cities all around the world are being built and re-invented as smart cities utilizing information systems and innovative applications of data analytics. One major smart cities component is transportation. The Intelligent Transportation Systems (ITS) industry is expected to grow at a rate of 19% per year and reach $5.5 Billion in annual investment by 2020. This shifting dynamic provides great opportunity for improved transportation safety and efficiency but also poses challenging information systems and public policy challenges. Furthermore, there are new opportunities for professional-school graduates outside of engineering schools for employment in transportation planning and policy. This course is supported by CMU's Traffic21 Initiative and Technologies for Safe and Efficient Transportation (T-SET) University Transportation Center. Classes will feature guest lectures provided by T-SET faculty and industry and government ITS professionals.

12-648 CEE Research Project

Fall and Spring
This course is designed to give students the opportunity to work on a research project under the direction of a faculty member in Civil and Environmental Engineering. A student in this course must write a proposal and submit progress reports to the advisor. The student must also make a presentation of the project results and submit a final report. To register for this course, a student must have the approval of the faculty member for both the research topic and the number of units.

12-651 Air Quality Engineering

Fall: 9 units
The course provides a quantitative introduction to the processes that control atmospheric pollutants and the use of mass balance models to predict pollutant concentrations. We survey major processes including emission rates, atmospheric dispersion, chemistry, and deposition. The course includes discussion of basic atmospheric science and meteorology to support understanding air pollution behavior. Concepts in this area include vertical structure of the atmosphere, atmospheric general circulation, atmospheric stability, and boundary layer turbulence. The course also discusses briefly the negative impacts of air pollution on society and the regulatory framework for controlling pollution in the United States. The principles taught are applicable to a wide variety of air pollutants but special focus is given to tropospheric ozone and particulate matter. The course is intended for graduate students as well as advanced undergraduates. It assumes a knowledge of mass balances, fluid mechanics, chemistry, and statistics typical of an undergraduate engineer but is open to students from other scientific disciplines.

12-657 Water Resource Systems Engineering

Spring: 9 units
Water Resource Systems Engineering combines hydrology, engineering, economics, and operations research to create tools and analyses that support decisions about large-scale water resource systems. The emphasis in this course will be on optimization methods, which are a core element of water systems analysis. Both water quantity and water quality problems will be covered.
Prerequisite: 12-355

12-659 Special Topics: Matlab

Fall: 6 units
This mini course is designed to be a practical introduction to engineering scientific computation. The topics of this class will include basic matrix computation, solving ordinary and partial differential equations, solving systems of linear equations, computing eigenvalues and eigenvectors, and basic signal processing and neural network techniques. Throughout the course, these scientific computation tools will be demonstrated using interactive scientific software called MATLAB.

12-690 CEE Independent Study

Fall and Spring
In-depth investigation of a special topic in Civil and Environmental Engineering under the direction of a faculty member. The subject of study is determined through discussion between the student and a faculty advisor. A student in this course must write a proposal about what they want to learn and how it can be evaluated. Approaches can include more in-depth examination of topics in the curriculum, study of topics not in the curriculum, a design project, or other investigation. To register for this course, a student must have the approval of the faculty member for both the subject and the number of units.

12-702 Fundamentals of Water Quality Engineering

Fall: 12 units
This course is a systematic overview of water quality engineering designed for students with no prior civil and environmental engineering background. Topics examined include physical, chemical, and biological characteristics of water; common water pollutants; basic water chemistry and microbiology; mass and energy balances and their use in reactor analysis; physical, chemical and biological processes affecting natural water quality and the use of these processes in water supply and wastewater management systems; and selected problems in surface water and groundwater quality management. A background in college-level general chemistry, physics, calculus, and differential equations is assumed.

12-704 Probability and Estimation Methods for Engineering Systems

Fall: 12 units
Overview of rules of probability, random variables, probability distribution functions, and random processes. Techniques for estimating the parameters of probability models and related statistical inference. Application to the analysis and design of engineered systems under conditions of variability and uncertainty.

12-712 Sustainable Engineering Principles

Fall: 12 units
This course presents an overview of the concept of sustainability, including changing attitudes and values toward technology and the environment through the late twentieth and early twenty-first centuries. Relevant issues in sustainable engineering, including population growth, urbanization, energy, water, food and material resources are discussed. Tools for sustainable engineering are presented, including metrics of sustainability, principles of design for the environment, and use of material and energy balances in sustainable systems. Publicly available data sets and computational models will be explored to assess sustainability. A team-based project is required.

12-714 Environmental Life Cycle Assessment

Spring: 12 units
Cradle-to-grave analysis of new products, processes and policies is important to avoid undue environmental harm and achieve extended product responsibility. This course provides an overview of approaches and methods for life cycle assessment and for green design of typical products and processes using the ISO 14040 family of standards. This includes goal and scoping definition, inventory analysis, life cycle impact assessment (LCIA), interpretation, and guidance for decision support. Process-based analysis models, input-output and hybrid approaches are presented for life cycle assessment. Example software such as MATLAB, Excel, and Simapro are introduced and used in assignments. A group life cycle assessment project consistent with the principles and tools of sustainability to solve real-world engineering problems is required.

12-720 Water Resources Chemistry

Fall: 12 units
This course provides a rigorous yet practical basis for applying the principles of physical chemistry to understanding the composition of natural waters and to the engineering of water and wastewater treatment processes. Topics covered include chemical equilibrium and kinetics; acid-base equilibria and buffering; solid precipitation and dissolution; oxidation and reduction reactions; adsorption on solids; and computer-aided problem solving. The primary objective of the course is to be able to formulate and solve chemical equilibrium models for complex aqueous systems. Knowledge of college-level general chemistry is assumed.

12-724 Biological Wastewater Treatment

Spring: 12 units
The exploitation of microbiological processes for environmental quality control is both historic and emergent. Engineered microbial systems have been used to treat wastewater for over 100 years, and they remain a critical component of modern operations. At the same time, new technologies are emerging to address modern challenges in the remediation and detoxification of hazardous chemicals and recovery of resources from waste. This course connects established principles of microbiology and engineering with empirical observations of complex microbial systems to develop quantitative tools for engineering biological systems. The course includes aerobic and anaerobic treatment perspectives as well as suspended growth and biofilm processes. Concepts are developed from a wastewater perspective but include applications in advanced, nutrient removal and resource recovery.

12-725 Fate, Transport & Physicochemical Processes of Orgnc Contaminants in Aqua Systms

Spring: 12 units
Examination of the major physical and chemical processes affecting the fate and treatment of organic compounds nanoparticles in aquatic systems. The emphasis is on anthropogenic organic compounds. The course will review some concepts from physical organic chemistry, and examine the relationships between chemical structure, properties, and environmental behavior of organic compounds. Chemical processes important to the fate, treatment, and biotransformation of specific organic compounds are addressed. Two laboratory sessions illustrate measurement techniques for organic compounds in water. 12-702 is a co- req for non environmental engineers or students who have not had and environmental engineering undergraduate course

12-726 Mathematical Modeling of Environmental Quality Systems

Spring: 12 units
Development and application of mathematical models for environmental systems. Material balance formulations and their solutions, computer implementation, model validation, uncertainty analysis, and use for projection and policy analysis. Applications to surface water, groundwater, atmospheric transport, indoor air pollution, and human exposure and risk.

12-740 Data Acquisition

Fall: 6 units
The intent of this course is to introduce students to the concepts, approaches and implementation issues associated with data acquisition for infrastructure systems. Students will be introduced to the types of data that is collected about infrastructure systems, excitation mechanisms, sensing technologies, data acquisition using sensors, signal pre-processing and post-processing techniques, and use of sensing in a variety of applications in construction and infrastructure management. Students will also gain experience with data acquisition hardware and software.

12-741 Data Management

Fall: 6 units
The intent of this course is to introduce students to database management systems and to knowledge discovery in database principles. Students will learn how to develop powerful tools for efficiently managing large amounts of civil engineering data so that it may persist safely over long periods of time. Students will be introduced to relational database systems and structured query languages. They will also be exposed to other existing data models. Students also will be introduced to data mining and analysis tools to discover patterns and knowledge from data.

12-746 Special Topics: Introduction to Python Prototyping for Infrastructure Systems

Fall: 6 units
This course uses the Python programming language to introduce fundamental programming approaches to students from civil and environmental engineering. No prerequisite required and students with no programming experience are recommended to take this course. This course will cover fundamental programming approaches, object-oriented programming concepts, graphical user interface design in Python, and file and database operation. Real-world examples from infrastructure management will be used in the class for demonstration and term project. Students will work individually and in teams to develop a series of applications that are potentially be used in real-world applications.

12-749 Climate Change Adaptation

Fall: 6 units
While the specific timing and magnitude of climate change impacts are uncertain, long-lived civil engineering infrastructure will need to be resilient to these potential impacts. Engineers designing for climate change adaptation require the tools to maximize resiliency and minimize cost for existing and proposed energy, transportation, water, urban and other types of infrastructure. Students successfully completing this course will understand how climate change affects civil infrastructure and how to quantitatively incorporate resilient designs and co-benefits under uncertainty. Students will use open data to examine current adaptation engineering challenges, quantify solutions, and communicate their technical recommendations through policy briefs. Prerequisites: Graduate standing or consent of instructor.

12-755 Finite Elements in Mechanics I

Fall: 12 units
The basic theory and applications of the finite element method in mechanics are presented. Development of the FEM as a Galerkin method for numerical solution of boundary value problems. Applications to second-order steady problems, including heat conduction, elasticity, convective transport, viscous flow, and others. Introduction to advanced topics, including fourth-order equations, time dependence, and nonlinear problems.Prerequisite: Graduate standing or consent of instructor.
Prerequisites: Graduate standing or consent of instructor.

Department of Electrical and Computer Engineering

Lawrence Pileggi, Coraluppi Head and Tanoto Professor

James Bain, Associate Head, Academic Affairs

Shawn Blanton, Associate Head, Research

Tamal Mukherjee, Associate Head, Students
www.ece.cmu.edu (http://www.ece.cmu.edu)

The field of electrical and computer engineering encompasses a remarkably diverse and expanding set of technologies, including embedded systems, intelligent physical systems, real-time software, distributed computing, mobile computing, cloud computing, digital signal processing, integrated circuits and electronics, computer architecture, intelligent robotic systems, computer-based control systems, telecommunications, computer networking, wireless communication systems, signal and information processing, multimedia systems, solid state physics and devices, microelectromechanical systems (MEMS), electromagnetic and electromechanical systems, and data storage systems. The extraordinary advances in these technologies during the last fifty years have impacted nearly every aspect of society and human activity. These advances have created new products and markets such as “smart” cars, cell phones and mobile computing systems, video games, and advanced medical systems for imaging, diagnosis, testing, and monitoring. These systems and products have served to enhance our quality of life and have also fueled the global economy. In short, the field of electrical and computer engineering has become central to society as we know it.

The Department of Electrical and Computer Engineering at Carnegie Mellon is actively engaged in education and research at the forefront of the existing and emerging technologies. Because of the diverse and broad nature of the field and the significant growth in knowledge in each of its sub areas, it is no longer possible for any single individual to know all aspects of electrical and computer engineering. Nevertheless, it is important that all electrical and computer engineers have a solid knowledge of the fundamentals with sufficient depth and breadth. Society is placing increasing demands on our graduates to apply their skills in new contexts. It is also placing increasing value on engineers who can cross traditional boundaries between disciplines and who can intelligently evaluate the broader consequences of their actions. Our curriculum is designed to produce world-class engineers who can meet these challenges.

Educational Outcomes and Objectives

The B.S. in Electrical and Computer Engineering is a broad and highly flexible degree program structured to provide students with a rich and comprehensive view of the profession. Minimal curriculum constraints enable every student to construct their own unique program of study that fits their professional goals. Students are encouraged to explore multiple areas of theory and application. Our program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org (https://www.abet.org/), under the commission’s General Criteria and Program Criteria for Electrical, Computer, Communications, Telecommunication(s) and Similarly Named Engineering Programs. The Faculty of Electrical and Computer Engineering have adopted the following outcomes from ABET and have established the following objectives for the B.S. in Electrical and Computer Engineering curriculum:

Student Outcomes

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. An ability to communicate effectively with a range of audiences
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

ECE program Educational Objectives

The ECE program objectives are shown below. They represent our vision for what our students will be doing in their engineering careers five years after they have graduated. The principal behaviors we seek to foster in our students are *expertise*, *innovation* and *leadership*.
Our graduates will be:

Experts

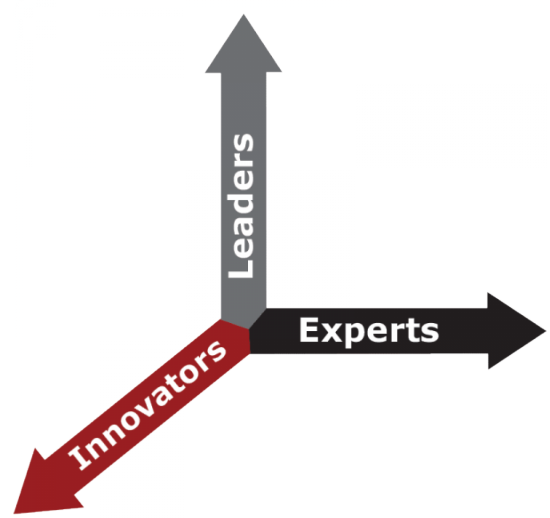
- They will solve problems by applying ECE fundamentals
- Their solutions will reflect depth of understanding in their sophistication.
- Their solutions will reflect breadth of understanding by drawing on multiple disciplines.

Innovators

- They will demonstrate creativity in their engineering practice.
- They will consider holistic systems-oriented approaches in their designs.
- They will think strategically in their planning and execution.

Leaders

- They will take initiative, and demonstrate resourcefulness.
- They will collaborate in multidisciplinary teams.
- They will be leaders in their organizations, their profession and in society.



Three dimensions of objectives for our graduates.

Curriculum Overview

The B.S. in Electrical and Computer Engineering is a broad and highly flexible ABET-accredited (http://www.abet.org) degree program offered on the Pittsburgh campus. It is structured to provide students with the smallest set of constraints consistent with a rich and comprehensive view of the profession. Students are encouraged and stimulated to explore multiple areas of theory and application from across the 5 principal undergraduate areas (https://www.ece.cmu.edu/academics/bs-in-ece/academic-guide.html) of Electrical and Computer Engineering. The sample curriculum (http://coursecatalog.web.cmu.edu/schools-colleges/collegeofengineering/departmentofelectricalandcomputerengineering/#samplecurriculumtext) highlights the flexibility of our curriculum while meeting the requirements listed below.

MINIMUM TOTAL UNITS REQUIRED FOR B.S. IN ELECTRICAL AND COMPUTER ENGINEERING 379

For detailed information and regulations of the curriculum along with the degree requirements and the most recent version of the ECE curriculum and course descriptions, please refer to the ECE Academic Guide (http://www.ece.cmu.edu/programs-admissions/bachelors/academic-guide/).

University Requirement

		Units
99-101	Core@CMU	3
		3

CIT Requirements (see CIT section of the catalog for specifics (p. 83)):

		Units
CIT General Education		72
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
One other introductory engineering course (generally taken during the freshman year)		12
33-141	Physics I for Engineering Students	12
33-142	Physics II for Engineering and Physics Students	12
15-112	Fundamentals of Programming and Computer Science	12
		140

GENERAL TECHNICAL REQUIREMENTS:

		Units
Two Math/Science electives [1]		18
Probability Requirement		
21-325	Probability	9
or 36-219	Probability Theory and Random Processes	
or 36-225	Introduction to Probability Theory	
18-202	Mathematical Foundations of Electrical Engineering [2]	12
21-127	Concepts of Mathematics [3]	12
or 21-128	Mathematical Concepts and Proofs	
15-122	Principles of Imperative Computation [4]	12
		63

[1]The Math/Science Electives may be satisfied by any course in The Mellon College of Science or the Department of Statistics except for: 100-level courses in Mathematics or Statistics, and courses designed for non-science or engineering majors, such as (but not limited to) 03-132, 09-103, 09-104, 21-240, 21-257, 21-261, 21-350, 33-115, 33-120, 33-124, 33-106, 33-107, 36-200, 36-201, 36-202, 36-203, 36-207, 36-208, 36-209, 36-210, 36-247, 36-309, and 36-310. Mathematics courses of particular interest to students in ECE are: 21-228 Discrete Mathematics, 21-241 Matrices and Linear Transformations, 21-259 Calculus in Three Dimensions, and 21-260 Differential Equations.

[2]This course can also be substituted by a combination of two of the following courses: 21-241, 21-242, 21-254, 21-259, 21-260, 21-268. Note that the combined total will therefore be 18 units.

[3]Effective Fall 2022. Prior to Fall 2022, 21-127 was 10 units.

[4]Effective Summer 2023. Prior to Summer 2023, 15-122 was 10 units.

ECE COURSE requirements:

For detailed information and regulations along with the degree requirements and the most recent version of the ECE curriculum and course descriptions, please refer to the ECE Academic Guide (https://www.ece.cmu.edu/academics/bs-in-ece/academic-guide.html).

		Units
ECE CORE COURSES		
18-100	Introduction to Electrical and Computer Engineering	12
18-200	ECE Sophomore Seminar	1
18-213	Introduction to Computer Systems	12
18-220	Electronic Devices and Analog Circuits	12
18-240	Structure and Design of Digital Systems	12
18-290	Signals and Systems	12
ECE AREA COURSES		
Two Area Courses from 1 of the 5 Areas within ECE		24
One additional Area Course from a second Area		12
ECE COVERAGE COURSES		
One Coverage Course (any additional ECE course or Approved CS course as listed on the ECE web site)		12
ECE CAPSTONE DESIGN		
Any 18-5xx course		12
		121

FREE ELECTIVES 52 units (typ)*

*For most students, the curriculum above will result in a remainder of 52 units of free electives to achieve the 379 required total units.

A Free Elective is defined as any graded course offered by any academic unit of the university. The large number of units without categorical constraints provides the student, in consultation with their Advisor or Mentor, with the flexibility to design a rich educational program.

Up to 9 units of Student Taught Courses (StuCo) and Physical Education courses, or other courses taken as Pass/Fail, may also be used toward Free Electives.

Transfer of courses from other premier universities may be accepted through submission of the Transfer Credit Request form on the CIT web page (https://xforms.andrew.cmu.edu/CITTransferCreditRequest/). Please see the CIT website (https://engineering.cmu.edu/education/academic-policies/undergraduate-policies/transfer-credit.html) for further information regarding the process.

Sample Curriculum

The table below shows a possible roadmap through our broad and flexible curriculum. The ECE Academic Guide (https://www.ece.cmu.edu/academics/bs-in-ece/academic-guide.html) provides further alternatives.

For First-Year requirements, please see the CIT section of the catalog for specifics (http://coursecatalog.web.cmu.edu/schools-colleges/collegeofengineering/#firstyearforengineeringstudentstext).

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
18-100 Introduction to Electrical and Computer Engineering	Introductory Engineering Course	18-200 ECE Sophomore Seminar	18-2xx ECE Core course
15-112 Fundamentals of Programming and Computer Science *	33-141 Physics I for Engineering Students *	18-2xx ECE Core Course	21-127 Concepts of Mathematics or 18-202 Mathematical Foundations of Electrical Engineering
21-120 Differential and Integral Calculus *	21-122 Integration and Approximation	18-202 Mathematical Foundations of Electrical Engineering or 21-127 Concepts of Mathematics	15-122 Principles of Imperative Computation
76-101 Interpretation and Argument	General Education course	33-142 Physics II for Engineering and Physics Students	36-219 Probability Theory and Random Processes
99-101 Core@CMU		General Education course	General Education course
		39-210 Experiential Learning I	39-220 Experiential Learning II

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
18-2xx ECE Core course	18-2xx ECE Core course	18-xxx ECE Coverage course	18-5xx ECE Capstone Design course
18-3xx/4xx ECE Area 1 course (first course in Area)	18-3xx/4xx ECE Area course (either 2nd course from Area 1 or the Area 2 course)	18-3xx/4xx ECE Area course (either 2nd course from Area 1 or the Area 2 course)	General Education course
Math/Science Elective 1	Math/Science Elective 2	General Education course	Free Electives as needed
General Education course	General Education course	Free Elective	Free Elective as needed
Free Elective	Free Elective	Free Elective	Free Elective as needed
39-310 Experiential Learning III			

*Note on AP credit:

Students who have AP credit for **Calculus** and/or **Physics** courses are encouraged to take 21-127 and/or 18-202.

- 21-127 is recommended for students interested in the Hardware Systems (https://www.ece.cmu.edu/academics/bs-in-ece/academic-guide.html) or Software Systems (https://www.ece.cmu.edu/academics/bs-in-ece/academic-guide.html) areas.
- 18-202 is recommended for students interested in the Device Science and Nanofabrication (https://www.ece.cmu.edu/academics/bs-in-ece/academic-guide.html), Signals and Systems (https://www.ece.cmu.edu/academics/bs-in-ece/academic-guide.html), or Circuits (https://www.ece.cmu.edu/academics/bs-in-ece/academic-guide.html) areas. An alternative to 18-202 is to take **two** other math courses. ECE undergraduates commonly take one or more of: 21-241, 21-259, and 21-260.

Students who have AP credit for **Computer Science A** are encouraged to first take 21-127, then to take 15-122.

Academic Policies

Policy on ECE Coverage Courses with Fewer than 12 Units

The basic curriculum requirements for Area courses, Coverage and Capstone Design are stated in terms of courses rather than units. The nominal total of 60 units for these categories is determined by assuming that each course is 12 units. In the event that courses with fewer than 12 units are used to satisfy some or all of these requirements, additional courses from the ECE coverage lists must be taken until the total units in ECE courses beyond the core meets or exceeds 60 units. Any ECE coverage course is acceptable, and any excess units beyond the required 60 may be counted as free elective credit.

Prerequisite Grade Requirements

Many ECE courses require a prerequisite course or courses. In most cases, the minimum grade required in a prerequisite to proceed on to the next course is a C. All prerequisites are listed in the registration system.

QPA Requirement and Overload Policy

An overload is defined as any schedule with more than 54 units in one semester. A student will only be permitted to overload by 12 units if she or he achieved an overall QPA of at least 3.5 out of 4.0. If the student's overall QPA is below a 3.5, then the QPA of the previous semester for which he or she is registering will instead be utilized. If that QPA is at least a 3.5 then the student will be permitted to Overload.

Grade Policy for Math Courses

1. CIT states that all mathematics (21-xxx) courses required* for the engineering degree taken at Carnegie Mellon must have a minimum grade of C in order to be counted toward the graduation requirement for the BS engineering degree.

2. A minimum grade of C must be achieved in any required mathematics (21-xxx) course that is a prerequisite for the next higher level required mathematics (21-xxx) course.

3. In addition, ECE requires that 18-202 Mathematical Foundations of Electrical Engineering must be completed with a grade of C or better.

*Elective mathematics courses (like the math/science electives required for ECE) are not included in this policy

Pass/Fail policy

Up to 9 units of StuCo and/or Physical Education courses or other courses taken as Pass/Fail may be used toward Free Electives. ECE core courses may not be taken as pass/fail. ECE project-based courses (including capstone design courses) may not be taken pass/fail. No ECE requirements may be fulfilled using a pass/fail course (except for 99-10x and 18-200)

Other Graduation Requirements

To be eligible to graduate, undergraduate students must complete all course requirements for their program with a cumulative Quality Point Average of at least 2.0. For undergraduate students who enrolled at Carnegie Mellon as freshmen and whose freshman grades cause the cumulative QPA to fall below 2.0, this requirement is modified to be a cumulative QPA of at least 2.0 for all courses taken after the freshman year. Note, however, the cumulative QPA that appears on the student's final transcript will be calculated based on all grades in all courses taken, including freshman year. Students are encouraged to confirm all graduation requirements with their academic advisor.

CIT has the following requirement for graduation. “Students must complete the requirements for their specified degrees with a cumulative quality point average of 2.00 or higher for all courses taken after the freshman year [this is the CIT QPA on the Academic Audit]. In addition, a student is expected to achieve a cumulative quality point average of 2.00 in a series of core departmental courses.”

In ECE, this means that the student must complete 18-100 Introduction to Electrical and Computer Engineering, ECE Core, Area Courses, Coverage, and Capstone Design courses with a minimum QPA of 2.0 to graduate. When more than one possibility exists for meeting a specific requirement (e.g., Area Course), the courses used for calculating the ECE QPA will be chosen so as to maximize the QPA. Similarly, when an ECE course is retaken, the better grade will be used in the computation of the minimum QPA for the ECE QPA requirement to graduate.

Other Opportunities in ECE

ECE Cooperative Education Program

Our Cooperative Education Program invites students to gain valuable experience in employment that relates directly to their major and career goals. At the same time, it provides employers with opportunities to evaluate students as potential full-time employees, while having them complete meaningful projects. Participation in this program is voluntary, and obtaining a cooperative education assignment is competitive.

Due to federal restrictions on student work experiences, international students are not eligible for co-ops. Please visit the ECE CPT page (http://www.ece.cmu.edu/programs-admissions/bachelors/cpt.html) for information regarding international student internships.

The co-op experience

We require a minimum of eight months of co-op experience to identify the work experience as a co-op. Students must have minimally completed their sophomore year to qualify for application to a co-op and should connect with their Academic Advisor for information on how to apply. While on co-op assignment, students are participating in a recognized CIT educational program, retaining their full-time student status, akin to our students who study abroad in established exchange programs (such as EPFL) for one or two semesters. The Cooperative Education Program agreement may be discontinued if the employers do not provide the students with career-related work experience or if the students do not meet the accepted level of performance as defined by the employers.

Upon returning to Carnegie Mellon, the students are required to submit for approval the following two documents to the ECE Undergraduate Office: a three to five page technical report of the Co-Op work, and a one page assessment and evaluation of the Co-Op experience.

Students may obtain more detailed information through the ECE department (http://www.ece.cmu.edu/programs-admissions/bachelors/cooperative-education-program.html) or the Career and Professional Development Center (http://www.cmu.edu/career/).

Teaching Assistantships

Teaching Assistants are a vital part of successful ECE course delivery. All ECE students will receive an email each semester when applications open for the upcoming semester, typically around the date the Schedule of Classes is published. Students are encouraged to communicate with the faculty of any course(s) they are interested in supporting, who can discuss the course expectations and staffing needs. Please see the ECE Teaching Assistantship website (https://www.ece.cmu.edu/insider/teaching-opportunities.html) for further information regarding these opportunities and how to apply.

Integrated M.S./B.S. Degrees Program

The Integrated Master's/Bachelor's program (http://www.ece.cmu.edu/programs-admissions/integrated/) (otherwise known as the IMB program) is an exciting opportunity for students who excel academically to achieve not just a Bachelor's degree in ECE, but also a Master's degree--through our Professional MS degree program--without needing to apply separately. This means no application fee, and no need to take the GRE (Graduate Record Exam). In order to be awarded the MS degree in the IMB program, the student must also earn their BS degree, either simultaneously with the MS degree or at least one semester prior to the awarding of the MS degree. If a course is eligible for the MS degree but must be used to complete the BS degree, the BS degree takes priority over the MS degree.

If a student is at least a 2nd semester junior, has completed at least 270 units and has at least an overall 3.00 QPA, he or she is guaranteed admission into the Professional MS degree in ECE through the IMB program. To be officially admitted, the student must complete the IMB Program form.

If a student does not meet the exact overall 3.00 QPA requirement, he or she is eligible to petition for his or her admission into the IMB program during his or her senior year. Students may obtain the petition forms through a meeting with their assigned academic advisor.

Professional MS Degree Requirements:

Please see the ECE web site for the requirements for the Professional MS degree (https://www.ece.cmu.edu/academics/ms-ece/standard-program.html). For students in the ECE IMB program, all requirements for the Professional MS degree are in addition to the requirements for the BS in ECE. No requirements for the MS degree may be used in any way toward the BS degree, including minors, additional majors or dual degrees.

Transition to graduate status:

Policies regarding completion and certification of the BS degree can be found on the Office of Enrollment Management's Standard Degree Requirements & Degree Certification (https://www.cmu.edu/es/advising-resources/degree-certification.html) webpage. Once the BS degree is certified, a student will be in graduate status for the subsequent term of enrollment. If a student takes more than 8 semesters to complete the BS degree, then he or she must be in graduate status for at least one semester before graduating with the MS degree. Once a student's undergraduate degree has been certified, no more courses may then be applied toward the BS degree. This includes courses toward minors and additional majors, although students pursuing an undergraduate dual degree with another department may still continue to apply additional coursework toward that second degree. Students should consult with Enrollment Services to understand how entering graduate status will affect financial aid, and with their academic advisor to determine a course schedule.

Faculty

DAVID ALLSTOT, Distinguished Special Professor of Electrical and Computer Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2023–

GEORGE AMVROSIADIS, Associate Research Professor of Electrical and Computer Engineering – Ph.D., University of Toronto, Canada; Carnegie Mellon, 2018–

JIM BAIN, Associate Department Head for Academic Affairs and Professor of Electrical and Computer Engineering and Materials Science Engineering; Associate Director, DSSC – Ph.D., Stanford University; Carnegie Mellon, 1993–

JAMES BARR VON OEHSEN, Research Professor of Electrical and Computer Engineering; Director, Pittsburgh Supercomputing Center (PSC) – Ph.D., Rutgers University ; Carnegie Mellon, 2023–

LUJO BAUER, Professor of Electrical and Computer Engineering – Ph.D., Princeton University; Carnegie Mellon, 2005–

THEO BENSON, Professor of Electrical and Computer Engineering – Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 2022–

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DAVID BRUMLEY, Professor of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2008–

MARK BUDNIK, Teaching Professor of Electrical and Computer Engineering – Ph.D., Purdue University; Carnegie Mellon, 2021–

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FRANZ FRANCHETTI, Kavčić-Moura Professor of Electrical and Computer Engineering; Associate Dean for Research, College of Engineering and Director, Engineering Research Accelerator – Ph.D., Vienna University of Technology; Carnegie Mellon, 2005–

GREGORY R. GANGER, Jatras Professor of Electrical and Computer Engineering; Director, Parallel Data Lab – Ph.D., University of Michigan; Carnegie Mellon, 1997–

PHILLIP GIBBONS, Professor of Electrical and Computer Engineering and Computer Science – Ph.D., University of California at Berkeley; Carnegie Mellon, 2015–

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CARLEE JOE-WONG, Robert E. Doherty Career Development Professor of Electrical and Computer Engineering – Ph.D., Princeton University; Carnegie Mellon, 2016–

GAURI JOSHI, Associate Professor of Electrical and Computer Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2017–

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HYONG S. KIM, Drew D. Perkins Professor of Electrical and Computer Engineering; Director, CMU-Thailand – Ph.D., University of Toronto; Carnegie Mellon, 1990–

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KEN MAI, Principal Systems Scientist of Electrical and Computer Engineering – Ph.D., Stanford University; Carnegie Mellon, 2005–

THERESA MAYER, Vice President for Research; Professor of Electrical and Computer Engineering and Materials Science and Engineering – Ph.D., Purdue University; Carnegie Mellon, 2023–

CRAIG MILLER, Research Professor of Electrical and Computer Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2020–

M. GRANGER MORGAN, Professor of Electrical and Computer Engineering; Hamerschlag University Professor of Engineering and Public Policy – Ph.D., University of California at San Diego; Carnegie Mellon, 1974–

JOSÉ M. F. MOURA, Philip L. and Marsha Dowd University Professor of Electrical and Computer Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1986–

TAMAL MUKHERJEE, Associate Department Head for Students and Professor of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1996–

WILLIAM NACE, Teaching Professor of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2008–

YORIE NAKAHIRA, Assistant Professor of Electrical and Computer Engineering – Ph.D., California Institute of Technology; Carnegie Mellon, 2020–

PRIYA NARASIMHAN, Professor of Electrical and Computer Engineering – Ph.D., University of California at Santa Barbara; Carnegie Mellon, 2001–

ROHIT NEGI, Professor of Electrical and Computer Engineering – Ph.D., Stanford University; Carnegie Mellon, 2000–

DAVID O'HALLARON, Professor of Electrical and Computer Engineering and Computer Science – Ph.D., University of Virginia; Carnegie Mellon, 1989–

SAMUEL PAGLIARINI, Special Professor of Electrical and Computer Engineering – Ph.D., Télécom Paris (now Institut Polytechnique de Paris), France; Carnegie Mellon, 2024–

BRYAN PARNO, Kavčić-Moura Professor of Electrical and Computer Engineering and Computer Science – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2017–

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LAWRENCE T. PILEGGI, Coraluppi Head and Tanoto Professor of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1996–

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BARRY RAWN, Associate Teaching Professor of Electrical and Computer Engineering – Ph.D., University of Toronto; Carnegie Mellon, 2018–

ANTHONY ROWE, Siewiorek and Walker Family Professor of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2009–

WILLIAM SANDERS, Dr. William D. and Nancy W. Strecker Dean, College of Engineering; Professor for Electrical and Computer Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2020–

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MARIOS SAVVIDES, Bossa Nova Robotics Professor of Artificial Intelligence for Electrical and Computer Engineering; Director, CyLab Biometrics Center – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2005–

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JOHN SHEN, Distinguished Service Professor of Electrical and Computer Engineering – Ph.D., University of Southern California; Carnegie Mellon, 2015–

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MICHAEL SKIRPAN, Assistant Teaching Faculty for Electrical and Computer Engineering; Executive Director, Community Forge – Ph.D., Colorado University at Boulder; Carnegie Mellon, 2019–

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PETER STEENKISTE, Professor of Electrical and Computer Engineering and Computer Science – Ph.D., Stanford University; Carnegie Mellon, 1993–

RICHARD STERN, Professor of Electrical and Computer Engineering; Language Technologies Institute, Computer Science, and BioMedical Engineering; Lecturer, Music – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1977–

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OZAN TONGUZ, Professor of Electrical and Computer Engineering – Ph.D., Rutgers University; Carnegie Mellon, 2000–

ELIAS TOWE, Professor of Electrical and Computer Engineering; Grobstein Professor of Materials Science and Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2001–

RIAD WAHBY, Assistant Professor of Electrical and Computer Engineering – Ph.D., Stanford University; Carnegie Mellon, 2022–

RAFAL WLODARSKI, Assistant Teaching Professor of Electrical and Computer Engineering; Carnegie Mellon University Silicon Valley – Ph.D., Lodz University of Technology, Poland; Carnegie Mellon, 2022–

OSMAN YAĞAN, Research Professor of Electrical and Computer Engineering – Ph.D., University of Maryland at College Park; Carnegie Mellon, 2013–

ZIAD YOUSSFI, Associate Teaching Professor of Electrical and Computer Engineering – Ph.D., Michigan State University; Carnegie Mellon, 2022–

BYRON YU, Professor of Electrical and Computer Engineering; Gerard G. Elia Career Development Professor of Biomedical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2010–

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JIMMY (JIAN-GANG) ZHU, ABB Professor of Electrical and Computer Engineering; Director DSSC; Professor of Materials Science and Engineering – Ph.D., University of California at San Diego; Carnegie Mellon, 1997–

Courtesy

YURVRAJ AGARWAL, Associate Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of California at San Diego; Carnegie Mellon, 2014–

BURCU AKINCI, Paul Christiano Professor and Department Head of Civil and Environmental Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Stanford University; Carnegie Mellon, 2000–

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SHENG SHEN, Professor of Mechanical Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2011–

JUSTINE SHERRY, Associate Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2017–

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REBECCA TAYLOR, Associate Professor of Mechanical Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Stanford University; Carnegie Mellon, 2016–

SRIDHAR TAYUR, Ford Distinguished Research Chair and Professor of Tepper School of Business; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Cornell University; Carnegie Mellon, 2017–

RASHMI VINAYAK, Associate Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2017–

WEINA WANG, Associate Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Arizona State University; Carnegie Mellon, 2018–

SHINJI WATANABE, Associate Professor of Language Technologies Institute; Courtesy Professor, Electrical and Computer Engineering – Ph.D., Waseda University, Tokyo, Japan; Carnegie Mellon, 2020–

SOSSENA WOOD, Assistant Professor of Biomedical Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Pittsburgh; Carnegie Mellon, 2022–

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Department of Electrical and Computer Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

18-059 Introduction to Amateur Radio

Spring: 3 units
Amateur radio is a pursuit that encompasses equal parts technology, communication, and public safety. It began in the US with the Radio Act of 1912, which guaranteed use of the electromagnetic spectrum to the people, provided they demonstrated the requisite technical competence. These privileges have persisted to the present day, with a vibrant global community of radio amateurs (hams) utilizing the spectrum to tinker and experiment with wireless communications for satellites, drone control, low-power communication, radio astronomy, and so on! This course will introduce students to the history, art, and science of radio with emphasis on hands-on demonstrations and in-class projects, including soldering a low-power FM transmitter and building a directional antenna. Students will also self-study to pass an amateur radio licensing exam administered on campus, which unlocks the electromagnetic spectrum for personal, non-commercial use. Radio service for public safety is tightly woven into the cultural fabric of the Buggy tradition at Carnegie Mellon, and becoming licensed is the first step to getting involved! Topics covered include: Radio signal fundamentals; Basic electronics; Antennas; Radio wave propagation; Radio equipment; Norms and culture of amateur radio communication; Operating regulations and safety Anyone interested in becoming a licensed amateur radio user is welcome regardless of major or prior background!

18-090 Twisted Signals: Multimedia Processing for the Arts

Spring: 10 units
[IDeATe portal course] - This course presents an overview on manipulating and synthesizing sound, video, and control signals. Signals are the raw materials used in many forms of electronic art and design - electronic music, interactive art, video art, kinetic sculpture, and more. In these fields, signals are used to represent information about sound, images, sensors, and movement. By transforming and manipulating these types of signals, we are able to create powerful new tools for digital art, multimedia applications, music, responsive environments, video and sound installation, smart products, and beyond. In this course we will study Signal Processing from a practical point-of-view, developing tools that can be easily integrated into art-making using the graphical programming environment Max (a.k.a. Max/MSP/Jitter). We will present a survey of Signal Processing techniques used in the sonic and visual arts, and will discuss the mathematical theories underlying these techniques. Students will be encouraged to combine, modify, and extend working examples of software to create original digital artworks.

18-095 Getting Started in Electronics: An Experiential Approach

Fall and Spring: 9 units
Electronics are ubiquitous and have transformed life many times over. Building circuits as a hobby has been a reliable introduction to a career in engineering for many decades, providing essential context and motivation for the mathematics and analysis techniques developed in the canonical ECE curriculum. For those with little prior knowledge of electronics, building circuits provides useful context and practical skills that lead to success in the rigorous engineering core. For those pursuing other career paths, exploring electronics develops technical literacy that will supplement and enhance their pursuits. Nowadays, the growth of maker culture has provided a wealth of tools that make electronics more accessible than ever before. This class uses an experiential learning approach to develop skills in circuit design, prototyping, and debugging. Every lecture is integrated with a hands-on laboratory experiment, punctuating each lesson with physical inquiry. The course will be based on two experiential learning texts: Getting Started in Electronics by Forrest Mims III, which has launched many engineering careers since the 1980s, and the modern classic Make: Electronics by Charles Platt. Principles of analog circuits, digital circuits, microcontrollers, and measurement equipment will be explored one experiment at a time, through twice-weekly integrated lecture/circuit builds and once-weekly self-guided builds.

18-100 Introduction to Electrical and Computer Engineering

Fall and Spring: 12 units
The goals of this freshman engineering course are: * To introduce basic concepts in electrical and computer engineering in an integrated manner; * To motivate basic concepts in the context of real applications; * To illustrate a logical way of thinking about problems and their solutions, and; * To convey the excitement of the profession. These goals are attained through analysis, construction and testing of an electromechanical system (e.g., a robot) that incorporates concepts from a broad range of areas within Electrical and Computer Engineering. Some of the specific topics that will be covered include system decomposition, ideal and real sources, Kirchhoff's Current and Voltage Laws, Ohm's Law, piecewise linear modeling of nonlinear circuit elements, Ideal Op-Amp characteristics, combinational logic circuits, Karnaugh Maps, Flip-Flops, sequential logic circuits, and finite state machines. 3 hrs. lec., 1 hr. rec., 3 hr. lab.

18-200 ECE Sophomore Seminar

Fall: 1 unit
The class comprises of a series of lectures from our own faculty and alumni, Department and University staff, and student groups. Students are required to attend each lecture. The lectures are designed to serve the following purposes: 1. Introduce to students to the faculty member's research field and the most current world advancements in engineering and technology in that area; 2. Provide students a good understanding of our curriculum structure and the courses in various areas; 3. Present correlations between the present technological developments and our courses for each course area; 4. Introduce new undergraduate courses; 5. Advertise on-campus/off-campus research opportunities for undergraduate students and explain the corresponding research projects; 6. Motivate students with positive presentations on the importance of obtaining education and gaining self-learning ability; 7. Provide basic education on learning and working ethics.

18-202 Mathematical Foundations of Electrical Engineering

Fall and Spring: 12 units
This course covers topics from engineering mathematics that serve as foundations for descriptions of electrical engineering devices and systems. It is the corequisite mathematics course for 18-220, Fundamentals of Electrical Engineering. The topics include: 1.MATLAB as a robust computational tool, used to reinforce, enrich and integrate ideas throughout the course, including software exercises and projects in combination with homework assignments; 2.Complex Analysis, including rectangular and polar representations in the complex plane with associated forms of complex arithmetic, powers, roots and complex logarithms, complex differentiation, analytic functions and Cauchy-Riemann equations, complex Taylor series, complex exponential, sinusoidal and hyperbolic functions, and Euler's formula; 3.Fourier Analysis, including orthogonality of sinusoids, trigonometric and exponential forms of Fourier series, Fourier integrals and Fourier transforms; 4.Linear, Constant-Coefficient Differential Equations, including complex exponential solutions to homogeneous equations and particular solutions with polynomial and sinusoidal driving functions described by phasors; 5.Difference Equations, with emphasis upon their relationship to differential equations, and; 6.Linear Algebra and Matrices, including matrix arithmetic, linear systems of equations and Gaussian elimination, vector spaces and rank of matrices, matrix inverses and determinants, eigenvalue problems and their relationship to systems of homogeneous differential equations.
Prerequisite: 21-122 Min. grade C

18-213 Introduction to Computer Systems

All Semesters: 12 units
This course provides a programmer's view of how computer systems execute programs, store information, and communicate. It enables students to become more effective programmers, especially in dealing with issues of performance, portability and robustness. It also serves as a foundation for courses on compilers, networks, operating systems, and computer architecture, where a deeper understanding of systems-level issues is required. Topics covered include: machine-level code and its generation by optimizing compilers, performance evaluation and optimization, computer arithmetic, memory organization and management, networking technology and protocols, and supporting concurrent computation. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course.
Prerequisite: 15-122 Min. grade C

18-220 Electronic Devices and Analog Circuits

Fall and Spring: 12 units
This course covers fundamental topics that are common to a wide variety of electrical engineering devices and systems. The topics include an introduction to semiconductor devices and technology, DC circuit analysis techniques, operational amplifiers, energy storage elements, sinusoidal steady-state response, frequency domain analysis, filters, and transient response of first- and second-order systems. The laboratories allow students to use modern electronic instrumentation and to build and operate circuits that address specific concepts covered in the lectures, including semiconductor devices and sensors, layout, operational amplifiers, filters, signal detection and processing, power converters and circuit transients. 3 hrs. lec., 1 hr. rec., 3 hrs. lab.
Prerequisite: 18-100 Min. grade C

18-224 Special Topics in Chip Design

Spring: 12 units
Please refer to the ECE website for descriptions of each topic: https://courses.ece.cmu.edu/

18-240 Structure and Design of Digital Systems

Fall and Spring: 12 units
This course introduces basic issues in design and verification of modern digital systems. Topics include: Boolean algebra, digital number systems and computer arithmetic, combinational logic design and simplification, sequential logic design and optimization, register-transfer design of digital systems, basic processor organization and instruction set issues, assembly language programming and debugging, and a hardware description language. Emphasis is on the fundamentals: the levels of abstraction and hardware description language methods that allow designers to cope with hugely complex systems, and connections to practical hardware implementation problems. Students will use computer-aided digital design software and actual hardware implementation laboratories to learn about real digital systems. 3 hr. lec., 1 hr. rec., 3 hr. lab.
Prerequisite: 18-100 Min. grade C

18-290 Signals and Systems

Fall and Spring: 12 units
This course develops the mathematical foundation and computational tools for processing continuous-time and discrete-time signals in both time and frequency domain. Key concepts and tools introduced and discussed in this class include linear time-invariant systems, impulse response, frequency response, convolution, filtering, sampling, and Fourier transform. Efficient algorithms like the fast Fourier transform (FFT) will be covered. The course provides background to a wide range of applications including speech, image, and multimedia processing, bio and medical imaging, sensor networks, communication systems, and control systems. This course serves as entry and prerequisite for any higher level course in the fields of signal processing, communications, and control.

18-300 Fundamentals of Electromagnetics

Fall: 12 units
This course introduces electromagnetic principles and describes ways in which those principles are applied in engineering devices and systems. Topics include: vector calculus as a mathematical foundation for field descriptions, Maxwell's equations in integral and differential forms with associated boundary conditions as descriptions of all electromagnetic principles, quasistatic electric fields in free space and in materials, superposition for known charge sources, conduction and polarization, resistance and capacitance, charge relaxation, analytic and numerical methods for electric field boundary value problems, quasistatic magnetic fields in free space and in materials, superposition for known current sources, magnetization, inductance, magnetic diffusion, and analytic and numerical methods for magnetic field boundary value problems. 4 hrs. lec.
Prerequisite: 18-220 Min. grade C

18-310 Fundamentals of Semiconductor Devices

Spring: 12 units
This course replaced 18311 in Spring 2005. In this course you will receive an introduction to the operation and fabrication of the most important semiconductor devices used in integrated circuit technology together with device design and layout. At the end of the course you will have a basic understanding of pn diodes, bipolar transistors, and MOSFETs as well as some light emitting and light detecting devices such as photodiodes, LEDs and solar cells. You will also receive an introduction to the fundamental concepts of semiconductor physics such as doping, electron and hole transport, and band diagrams. In the laboratory you will learn how to lay out both bipolar and MOS devices and you will design small (2-3 transistor) circuits. The laboratory portion of the course emphasizes the relation between device design and layout and circuit performance. You will also experimentally evaluate the operation of amplifier and gate circuits fabricated with discrete devices. This course will give you an excellent understanding of the operation and fabrication of the devices which is necessary for high-performance analog and digital circuit design. 3 hrs. lec. (Note: the prerequisite is typically waived for MSE students who intend to pursue the Electronic Materials Minor.)
Prerequisite: 18-220 Min. grade C

18-320 Microelectronic Circuits

Spring: 12 units
18-320 introduces students to the fundamentals of microelectronic circuits. The course will emphasize the analysis and design of basic analog and digital integrated circuits in preparation for further study in analog, digital, mixed-signal, and radio-frequency integrated circuit design. Additionally, students will learn to design and analyze microelectronic circuits using industry standard computer aided design (CAD) software. Topics to be covered include: MOSFET fabrication and layout MOSFET models for analog and digital design Analysis and design of digital CMOS logic gates Analysis and design of clocked storage elements (e.g., flip-flops, latches, memory cells) Delay optimization of digital circuits Circuit topologies for arithmetic and logical functional units Analysis and design of single-stage MOS amplifiers Frequency response characteristics of single-stage amplifiers Differential amplifiers and simple operational amplifiers Analog filters using operational amplifiers The course includes a lab component which will give students hands-on experience in the design and implementation of analog and digital circuits. Labs will employ both design using discrete, SSI, and MSI parts, as well as using CAD design tools.
Prerequisite: 18-220 Min. grade C

18-330 Introduction to Computer Security

Fall and Spring: 12 units
Security is becoming one of the core requirements in the design of critical systems. This course will introduce students to the intro-level fundamental knowledge of computer security and applied cryptography. Students will learn the basic concepts in computer security including software vulnerability analysis and defense, networking and wireless security, and applied cryptography. Students will also learn the fundamental methodology for how to design and analyze security critical systems.
Prerequisite: 18-213 Min. grade C

18-334 Network Security

Spring: 12 units
Some of today's most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to advance attacks on end systems. This course provides an in-depth study of network attack techniques and methods to defend against them. The course will cover topics spanning five broad themes: (1) infrastructure topics such as firewalls, network intrusion detection, secure routing protocols, and recent advances such as software-defined networking; (2)network attacks such as denial of service (DoS) and distributed denial-of-service (DDoS) attacks, worm and virus propagation; (3)analysis and inference topics such as network forensics and attack economics; (4) user related topics such as authentication, anonymity and censorship resilience; and (5) new technologies related to next-generation networks, and cellular and wireless networks. Students in 18-334 will share lectures and homeworks with students in 18-731. However, 18-731 will have additional requirements not shared by 18-334, including the requirement to produce scribe notes and to practice and demonstrate the ability to read and summarize scientific papers on the topics covered by the course.
Prerequisites: 18-330 Min. grade C or 15-330 Min. grade C

18-335 Secure Software Systems

Spring: 12 units
Poor software design and engineering are the root causes of most security vulnerabilities in deployed systems today. Moreover, with code mobility now commonplace and #8212;particularly in the context of web technologies and digital rights management and #8212;system designers are increasingly faced with protecting hosts from foreign software and protecting software from foreign hosts running it. This class takes a close look at software as a mechanism for attack, as a tool for protecting resources, and as a resource to be defended. Topics covered include the software design process; choices of programming languages, operating systems, databases and distributed object platforms for building secure systems; common software vulnerabilities, such as buffer overflows and race conditions; auditing software; proving properties of software; software and data watermarking; code obfuscation; tamper resistant software; and the benefits of open and closed source development. Students in 18-335 will share lectures and homeworks with students in 18-732. However, 18-732 has additional requirements not shared by 18-335, including the requirement to produce scribe notes and to practice and demonstrate the ability to read and summarize scientific papers on the topics covered by the course.
Prerequisites: (15-330 Min. grade C or 18-631 Min. grade C or 14-741 Min. grade C or 18-730 Min. grade C or 18-330 Min. grade C) and (15-213 Min. grade C or 18-613 Min. grade C or 15-513 Min. grade C or 14-513 Min. grade C or 18-213 Min. grade C)

18-340 Hardware Arithmetic for Machine Learning

Fall: 12 units
In this course, students explore the techniques for designing high-performance digital circuits for computation along with methods for evaluating their characteristics. We begin by reviewing number systems and digital arithmetic along with basic arithmetic circuits such as ripple-carry adders. From there, we move to more complex adders (carry-look-ahead, carry-skip, carry-bypass, etc.), multipliers, dividers, and floating-point units. For each circuit introduced, we will develop techniques and present theory for evaluating their functionality and speed. Other methods will be described for analyzing a circuit's power consumption, testability, silicon area requirements, correctness, and cost. In addition, we will utilize various CAD tools to evaluate the circuits described. Finally, advanced timing and clocking concepts will be investigated. For example, the notion of clock skew will be introduced and its impact on clock period for sequential circuits will be analyzed. We will also learn how to analyze and design asynchronous circuits, a class of sequential circuits that do not utilize a clock signal. Course projects focus on key arithmetic aspects of various machine learning algorithms including: K-nearest neighbors, neural networks, decision trees, and support vector machines. *Note: Although students in 18-340 and 18-640 will share lectures, labs, and recitations, students in 18-340 and 18-640 will receive different homework assignments, design projects, and exams. In some cases 18-640 students will also have different or additional lab sessions. The homework assignments, design projects, and exams that are given to the students registered for 18-640 will be more challenging than those given to the students registered for 18-340 in that they will have more complex designs, involve additional theoretical analysis, and have more stringent specifications (e.g., in area, power, performance, and robustness).
Prerequisite: 18-240 Min. grade C

18-341 Logic Design and Verification

Fall and Spring: 12 units
This course is a second level logic design course, studying the techniques of designing at the register-transfer and logic levels of complex digital systems using modern modeling, simulation, synthesis, and verification tools. Topics include register-transfer level systems (i.e., finite state machines and data paths), bus and communication system interfacing (such as a simplified USB interface), discrete-event simulation, testbench organization, assertion-based verification and functional coverage. Design examples will be drawn from bus and communication interfaces, and computation systems, emphasizing how these systems are designed and how their functionality can be verified. A modern hardware description language, such as SystemVerilog, will serve as the basis for uniting these topics. Quizzes, homeworks and design projects will serve to exercise these topics.
Prerequisite: 18-240 Min. grade C

18-344 Computer Systems and the Hardware-Software Interface

Fall: 12 units
This course covers the design and implementation of computer systems from the perspective of the hardware software interface. The purpose of this course is for students to understand the relationship between the operating system, software, and computer architecture. Students that complete the course will have learned operating system fundamentals, computer architecture fundamentals, compilation to hardware abstractions, and how software actually executes from the perspective of the hardware/software boundary. The course will focus especially on understanding the relationships between software and hardware, and how those relationships influence the design of a computer system's software and hardware. The course will convey these topics through a series of practical, implementation-oriented lab assignments.
Prerequisites: 18-213 Min. grade C and 18-240 Min. grade C

18-349 Introduction to Embedded Systems

Fall and Spring: 12 units
This practical, hands-on course introduces the various building blocks and underlying scientific and engineering principles behind embedded real-time systems. The course covers the integrated hardware and software aspects of embedded processor architectures, along with advanced topics such as real-time, resource/device and memory management. Students can expect to learn how to program with the embedded architecture that is ubiquitous in cell-phones, portable gaming devices, robots, PDAs, etc. Students will then go on to learn and apply real-time principles that are used to drive critical embedded systems like automobiles, avionics, medical equipment, the Mars rover, etc. Topics covered include embedded architectures (building up to modern 16/32/64-bit embedded processors); interaction with devices (buses, memory architectures, memory management, device drivers); concurrency (software and hardware interrupts, timers); real-time principles (multi-tasking, scheduling, synchronization); implementation trade-offs, profiling and code optimization (for performance and memory); embedded software (exception handling, loading, mode-switching, programming embedded systems). Through a series of laboratory exercises with state-of-the-art embedded processors and industry-strength development tools, students will acquire skills in the design/implementation/debugging of core embedded real-time functionality.
Prerequisites: 18-213 Min. grade C and 18-240 Min. grade C

18-351 Full-Stack Software Development for Engineers

Fall and Spring: 12 units
This course will introduce the principles, concepts, technologies, and practices of full-stack software development for creating end-to-end web applications using a classical client-server architecture and the model-view-controller pattern. Students will acquire basic front-end and back-end skills and learn how to apply modern development practices in the context of an individual hands-on project using the plain web stack for the front-end, TypeScript and a NoSQL database layer for the back-end, and other common libraries, light-weight frameworks, and tools as adjuncts. They will practice how to version-control the codebase, manage a small project, transform requirements expressed as user stories into working software in an incremental manner, maintain code quality, build their application on an integration server, and deploy it on the cloud. To enroll in this course, students must already be proficient in coding using multiple programming languages and familiar with the basics of algorithms, data structures, databases, and software design principles, including object-orientation. Each student will need their own laptop computer to use in the course.
Prerequisite: 15-122 Min. grade B

18-352 Software Engineering Essentials

Spring: 12 units
In this course, students will learn about and apply software engineering paradigms that have shaped the software industry over the past few decades. They will be exposed to fundamental disciplines of software engineering as well as central engineering practices that crosscut system, project, and user perspectives. They will iteratively analyze and implement user requirements in the presence of a customer proxy, and architect, design, implement, integrate, test, and deploy an evolving solution that balances multiple engineering and user constraints. The course is organized around a semester-long team project with frequent milestones, deliverables, demonstrations, and assessments. Newly introduced course topics are immediately applied to the team project. The team project starts right away and relies on several software technologies, tools, and stacks: prior knowledge of these elements is therefore paramount. To enroll, students must have substantial programming experience and be already familiar with these elements. This course can replace 18652 to satisfy a core requirement of ECEs MS-SE program.
Prerequisites: 18-351 Min. grade C or 17-437

18-358 Special Topics in Communications

Spring: 6 units
Please go to the ECE website to view "Special Topics in Communications" course descriptions.

Course Website: https://courses.ece.cmu.edu/

18-370 Fundamentals of Control

Fall: 12 units
This junior/senior-level undergraduate course introduces the fundamental principles and methodologies of classical feedback control of linear systems and its applications. Emphasis is on understanding physical principles in feedback systems, practical problem formulation and the analysis and synthesis of feedback control systems using frequency and time domain techniques. The covered material provides a foundation for further studies toward careers in motion control, automation, control electronics, robotics, systems science and engineering. The practical knowledge in this course represents necessary tools to design a broad variety of systems such as robots, servo and tracking systems, feedback circuits, phase-locked loops, and microelectromechanical systems. Topics include analytical, graphical and computer-aided techniques (MATLAB/Simulink) for analyzing, designing and realizing of feedback control systems; Laplace transforms and associated transfer function modeling; root-locus and frequency response (Bode plot) design; pole-zero synthesis techniques; analysis of trade-offs in performance: stability, transient response, steady-state error, disturbance rejection, and robustness; design and implementation of PID, lead-lag, and loop shaping compensators. If time permits, the course will include a cursory introduction to state space modeling, systems with delay and computer control systems.
Prerequisites: 18-290 Min. grade C or 24-352 Min. grade C

18-372 Fundamental Electrical Power Systems

Fall: 12 units
This course introduces the fundamentals in electric energy systems which will enable you to understand current issues and challenges in electric power systems ("smart grid") and what it takes for you to have a reliable electric power supply at your house. First, the general structure of an electric power system (current and future trends) will be introduced. This includes electric power plants (renewable and non-renewable); transmission and distribution; and consumers. Then, electric power is addressed from a mathematical point of view. The mathematical formulae for AC power and models for the above mentioned elements are derived which will enable you to calculate how much power is flowing over which lines on its way from the power plant to the consumer. Maintaining the balance between generation and consumption is important to avoid catastrophic blackout events. Hence, the notion of stability and available control concepts will be introduced.
Prerequisite: 18-220 Min. grade C

18-390 ECE CO-OP

All Semesters
The Department of Electrical and Computer Engineering at Carnegie Mellon considers experiential learning opportunities important educational options for its undergraduate students. One such option is cooperative education, which provides a student with an extended period of exposure with a company. To participate, students must work with their academic advisor to complete an ECE Co-op Approval form and submit for approval. Students must possess at least junior status and have an overall grade point average of 3.0 or above. All co-ops must be approximately 8 months in uninterrupted length. If the co-op is approved, the ECE Undergraduate Studies Office will add the course to the student's schedule. Upon completion of the co-op experience, students must submit a 1-2 page report of their work experience, and a 1-2 page evaluation from the company supervisor to the ECE Undergraduate Office. International students should also be authorized by the Office of International Education (OIE). More information regarding CPT is available on OIE's website.

18-399 Special Topics in Signal Processing

Intermittent: 3 units
Please refer to the ECE website to view "Special Topics in Signal Processing" course descriptions. http://www.ece.cmu.edu/courses/index.html (http://www.ece.cmu.edu/courses/)

18-401 Electromechanics

12 units
This course provides a broadly based introduction to interactions between mechanical media and electromagnetic fields. Attention is focused on the electromechanical dynamics of lumped-parameter systems, wherein electrical and mechanical subsystems may be modeled in terms of discrete elements. Interactions of quasistatic electric and magnetic fields with moving media are described and exemplified. Unifying examples are drawn from a wide range of technological applications, including energy conversion in synchronous, induction, and commutator rotating machines, electromechanical relays, a capacitor microphone and speaker, and a feedback-controlled magnetic levitation system. 4.5 hrs. rec.
Prerequisite: 18-300

18-402 Applied Electrodynamics

Spring: 12 units
This course builds upon the electric and magnetic field foundations established in 18-300 to describe phenomena and devices where electromagnetic waves are a central issue. Topics include: review of Maxwell's equations, propagation of uniform plane waves in lossless and lossy media, energy conservation as described by the Poynting Theorem, reflection and transmission with normal and oblique incidence upon boundaries, sinusoidal steady state and transients on 2-conductor transmission lines, modal descriptions of waveguides, radiation and antennas. 4 hrs. lec.
Prerequisite: 18-300

18-403 Microfabrication Methods and Technology

Fall: 12 units
This course is a laboratory-based introduction to the theory and practice of microfabrication. Lectures and laboratory sessions cover fundamental processing techniques such as photo-mask creation, lithographic patterning, thin film vacuum deposition processes, wet-chemical and dry-etching processes. This is primarily a hands-on laboratory course which brings students into the microfabrication facility and device testing laboratories. Students will fabricate electronic and opto-electronic devices such the metal-oxide-semiconductor (MOS) capacitor, the Schottky diode, the MOS transistor, the solar cell, and the light-emitting diode. An understanding of the operation of these building block devices will be gained by performing measurements of their electrical and opto-electronic characteristics. Emphasis is placed on understanding the interrelationships between the materials properties, processing, device structure, and the electrical and optical behavior of the devices. The course is intended to provide a background for a deeper appreciation of solid state electronic devices and integrated circuits. 2 lecture periods per week and a minimum of 4 laboratory hours.
Prerequisite: 18-310

18-411 Computational Techniques for Data Science and Engineering

Spring: 12 units
This course covers mathematical techniques that permit formulation of equations that often emerge out of engineering and science problems or experimental data in a manner that makes them computationally tractable for numerical solutions and analysis. Numerical approaches to solving engineering or science equations allow one to perform computer simulations that can often answer key questions without actual experimentation (which can be costly and time-consuming). The course is divided into two major modules. The first develops foundational background in modeling, computers, error analysis, linear algebra, regression, and curve fitting. To illustrate applications of the main concepts of the first module, we discuss how to use them in machine learning, specifically in deep learning. Students carry out a deep learning project of their choosing to sharpen their comprehension of both the mathematics behind deep learning, and the machine learning algorithms that enable the most common applications of deep learning. The second module builds on the first to develop skills in numerical differentiation and integration and continues with techniques for computational solution of ordinary and partial differential equations that arise from physical or engineering problems. Students learn how to set up these equations in a manner that allows numerical solutions to be obtained by either writing simple computer code or macros that interface with open-source Python code or commercially available software packages such as MATLAB or Mathematica.
Prerequisites: (15-110 Min. grade C or 15-112) and 21-120

18-416 Nano-Bio-Photonics

Spring: 12 units
Light can penetrate biological tissues non-invasively. Most of the available bio-optic tools are bulky. With the advent of novel nanotechnologies, building on-chip integrated photonic devices for applications such as sensing, imaging, neural stimulation, and monitoring is now a possibility. These devices can be embedded in portable electronic devices such as cell phones for point of care diagnostics. This course is designed to convey the concepts of nano-bio-photonics in a practical way to prepare students to engage in emerging photonic technologies. The course starts with a review of electrodynamics of lightwaves. The appropriate choice of wavelength and material platform is the next topic. Then optical waveguides and resonators are discussed. Resonance-based sensing is introduced followed by a discussion of the Figure of Merits (FOMs) used to design on-chip sensors. Silicon photonics is introduced as an example of a CMOS-compatible platform. On-chip spectroscopy is the next topic. The second part covers nano-plasmonics for bio-detection and therapy. The design methods are discussed, followed by an overview of nanofabrication and chemical synthesis, and then a discussion of applications. The last part of this course will be dedicated to a review of recent applications such as Optogenetic neural stimulation, Calcium imaging, Cancer Imaging and Therapy. Senior or graduate standing required. This course is cross-listed with 18616. Although students in 18-616 and 18-416 will share the same lectures and recitations, students in 18-616 will receive distinct course projects. Students in 18-416 and 18-616 will be graded on separate curves.
Prerequisite: 18-300 Min. grade C

18-420 Design, Integration, and Tapeout of IoT Systems

Fall: 12 units
This course provides a comprehensive exploration of the design concepts and methodologies involved in developing integrated circuits for Internet of Things (IoT) systems. Students will gain hands-on experience in designing and integrating essential blocks such as sensor front-ends, data converters, machine learning circuits, and wireless transmitters. Key concepts include an introduction to IoT system architectures, principles of sensor interfacing, analog-to-digital converters (ADCs), machine learning in IoT, RF front-end design considerations, an CMOS technology and design rules, overview of the tapeout process, and design exercises using industry-standard design tools. By bringing together individual blocks into a cohesive system, students will gain the skills and knowledge required to design, simulate, and tapeout a complete IoT system-on-chip by the end of this course. The course emphasizes a practical, project-based approach to ensure students are well-prepared for real-world challenges in IoT integrated circuit design. This course is crosslisted with 18620. ECE graduate students will be prioritized for 18620, and ECE undergraduate students will be prioritized for 18420. Although students in 18420 will share lectures with students in 18620, students in 18620 will undertake more complex projects.
Prerequisite: 18-220 Min. grade C

18-421 Analog Integrated Circuit Design

Fall: 12 units
Some form of analog circuit design is a critical step in the creation of every modern IC. First and foremost, analog circuits act as the interface between digital systems and the real world. They act to amplify and filter analog signals, and to convert signals from analog to digital and back again. In addition, high performance digital cell design (either high speed or low power) also invokes significant analog circuit design issues. The goal of this course is to teach students some of the methods used in the design and analysis of analog integrated circuits, to illustrate how one approaches design problems in general, and to expose students to a broad cross-section of important analog circuit topologies. The course will focus on learning design through carrying out design projects. Design and implementation details of wide-band amplifiers, operational amplifiers, filters and basic data converters will be covered. Example topics to be covered include transistor large- and small-signal device models, small-signal characteristics of transistor-based amplifiers, large-signal amplifier characteristics and nonidealities, operational amplifier design, basic feedback amplifier stability analysis and compensation, and comparator design. The course will focus primarily on analog CMOS, but some aspects of BJT design will be discussed. 18-290 and 18-320 or equivalent background material with permission of the instructor. Although students in 18-623 will share Lectures and Recitations with students in 18-421, students in 18-623 will receive distinct homework assignments, distinct design problems, and distinct exams from the ones given to students in 18-421 and will be graded on a separate curve from students taking 18-421.
Prerequisites: 18-290 Min. grade C and 18-320 Min. grade C

18-422 Digital Integrated Circuit Design

Fall: 12 units
This course covers the design and implementation of digital circuits in a modern VLSI process technology. Topics will include logic gate design, functional unit design, latch/flip-flop design, system clocking, memory design, clock distribution, power supply distribution, design for test, and design for manufacturing. The lab component of the course will focus on using modern computer aided design (CAD) software to design, simulate, and lay out digital circuits. The final project for the course involves the design and implementation to the layout level of a small microprocessor. Although students in 18-422 and 18-622 will share lectures, labs, and recitations, students in 18-422 and 18-622 will receive different homework assignments, design projects, and exams, and in some cases 18-622 students will also have different or additional lab sessions.
Prerequisites: 18-320 Min. grade C and 18-240 Min. grade C

18-427 Board-Level RF Systems for the Internet-of-Things

Fall: 12 units
In this age when everything is connected to the internet-of-things (IOT), students should understand how RF Transceivers and Antennas can allow such devices to be connected without wires. This class will give students the chance to learn about cellular and IOT devices and how they communicate using radio frequency (RF) signals. Students will gain an understanding of antenna design and operation, a high-level understanding of RF signal propagation, an introduction to RF Transceiver design and operation and an overview of multi-input multi-output (MIMO) RF operation. A Laboratory section is included in this class. In Lab, students will learn how to assemble printed circuit board (PCBs) using the Tech Spark facility. Early Lab sessions will demonstrate RF signals, antennas, and constructive and destructive RF interference. Students control the RF transceiver ICs by programming several different types of software defined radios (SDRs). Several different PCB antenna designs will be explored in the Lab sessions. Lab exercises will culminate with students building up an SDR-controlled RF transmitter driving a PCB antenna and using it to send data from one student to another using MI O beam steering to increase spectral reuse. Although students in 18-727 will share lectures and recitations with students in 18-427, students in 18-727 will receive distinct homework assignments and grading scale from students in 18-427. Specifically, the homework assignments for 18-727 will be more complex than the homework assignments for 18-427.
Prerequisites: 18-290 Min. grade B and 18-320 Min. grade B

18-435 Foundations of Blockchains

Fall: 12 units
In this course, students will learn the mathematical foundations of blockchains, including how to construct distributed consensus protocols and prove them secure, cryptography for blockchains, and mechanism design for blockchains. This course will take a mathematically rigorous approach. Students are expected to have mathematical maturity and be able to write formal mathematical proofs. Students may also be expected to implement some consensus or cryptographic algorithms. This course is crosslisted with 18635. ECE graduate students will be prioritized for 18635, and ECE undergraduate students will be prioritized for 18435. Although students in 18435 will share lectures with students in 18635, students in 18435 will receive distinct homework assignments, distinct programming projects, and distinct exams from the ones given to students in 18635. Specifically, the homework assignments, programming projects, and exams that are given to the 18635 students will be more challenging than those given to the 18435 students.
Prerequisites: 18-334 Min. grade C or 18-335 Min. grade C or 18-465 Min. grade C or 18-733 Min. grade C or (18-202 Min. grade C and 18-213 Min. grade C) or (18-202 Min. grade C and 15-513 Min. grade C) or (18-202 Min. grade C and 18-613 Min. grade C) or (14-513 Min. grade C and 18-202 Min. grade C)

18-441 Computer Networks

Intermittent: 12 units
The Internet has transformed our everyday lives, bringing people closer together and powering multi-billion dollar industries. The mobile revolution has brought Internet connectivity to the last-mile, connecting billions of users worldwide. But how does the Internet work? What do oft repeated acronyms like "LTE", "TCP", "WWW" or a "HTTP" actually mean and how do they work? This course introduces fundamental concepts of computer networks that form the building blocks of the Internet. We trace the journey of messages sent over the Internet from bits in a computer or phone to packets and eventually signals over the air or wires. We describe concepts that are common to and differentiate traditional wired computer networks from wireless and mobile networks. Finally, we build up to exciting new trends in computer networks such as the Internet of Things, 5-G and software defined networking. Topics include: physical layer and coding (CDMA, OFDM, etc.); data link protocol; flow control, congestion control, routing; local area networks (Ethernet, Wi-Fi, etc.); transport layer; and introduction to cellular (LTE) and 5-G networks. A final project asks you to a build a HTTP video server of your own. This course is cross-listed with 18-741 - both editions will share Lectures and Recitations. However, students in the two courses will receive different exams and will have a different project. The students in the two versions of the course will be graded on a separate curve.
Prerequisite: 18-213 Min. grade C

18-447 Introduction to Computer Architecture

Spring: 12 units
Computer architecture is the science and art of selecting and interconnecting hardware components to create a computer that meets functional, performance and cost goals. This course introduces the basic hardware structure of a modern programmable computer, including the basic laws underlying performance evaluation. We will learn, for example, how to design the control and data path hardware for a MIPS-like processor, how to make machine instructions execute simultaneously through pipelining and simple superscalar execution, and how to design fast memory and storage systems. The principles presented in the lecture are reinforced in the laboratory through the design and simulation of a register transfer (RT) implementation of a MIPS-like pipelined superscalar in Verilog. Learning to design programmable systems requires that you already have the knowledge of building RT systems, the knowledge of the behavior storage hierarchies (e.g., cache memories) and virtual memory, and the knowledge of assembly language programming.
Prerequisites: 18-240 Min. grade C and (18-213 Min. grade C or 15-213 Min. grade C) and (18-330 Min. grade C or 18-349 Min. grade C or 18-320 Min. grade C or 18-340 Min. grade C or 18-341 Min. grade C or 18-344 Min. grade C)

18-448 Special Topics in Embedded Systems

Intermittent: 12 units
Please refer to the ECE website for descriptions of each topic.

Course Website: https://courses.ece.cmu.edu/

18-452 Wireless Networking and Applications

Spring: 12 units
This course introduces fundamental concepts of wireless networks. The design of wireless networks is influenced heavily by how signals travel through space, so the course starts with an introduction to the wireless physical layer, presented in a way that is accessible to a broad range of students. The focus of the course is on wireless MAC concepts including CSMA, TDMA/FDMA, and CDMA. It also covers a broad range of wireless networking standards, and reviews important wireless network application areas (e.g., sensor networks, vehicular) and other applications of wireless technologies (e.g., GPS, RFID, sensing, etc.). Finally, we will touch on public policy issues, e.g., as related to spectrum use. The course will specifically cover: Wireless networking challenges Wireless communication overview Wireless MAC concepts Overview of cellular standards and LTE Overview of wireless MAC protocols WiFi, bluetooth and personal area networks, etc. Wireless in today's Internet: TCP over wireless, mobility, security, etc. Advanced topics, e.g., mesh and vehicular networks, sensor networks, DTNs, localization, sensing, etc. Although students in 18-750 will share Lectures and Recitations with students in 18-452, they will receive distinct homework assignments and exams from students in 18-452. The main project will also be different. The students in the two versions of the course will also be graded on a separate curve.
Prerequisites: 15-213 Min. grade C or 18-613 Min. grade C or 18-213 Min. grade C

18-453 Introduction to XR Systems

Fall: 12 units
Digitization of reality is at the cusp of widespread adoption; it also embodies a unique convergence of techniques that span the gamut of electrical and computer engineering. This course introduces students to augmented/virtual/mixed reality systems, or what is broadly referred to as extended reality (XR). The course covers hardware and software topics central to XR systems, namely, content capture, streaming, and display, looking at both commercial and research- grade systems. A course project will allow students to experience and innovate in this space.
Prerequisites: 18-213 Min. grade C or 18-290 Min. grade C

18-460 Optimization

Spring: 12 units
Many design problems in engineering (e.g., machine learning, finance, circuit design, etc.) involve minimizing (or maximizing) a cost (or reward) function. However, solving these problems analytically is often challenging. Optimization is the study of algorithms and theory for numerically solving such problems, and it underpins many of the technologies we use today. This course is an introduction to optimization. Students will: (1)learn about common classes of optimization problems, (2) study (and implement) algorithms for solving them, and (3) gain hands-on experience with standard optimization tools. We will focus on convex optimization problems, but will also discuss the growing role of non-convex optimization, as well as some more general numerical methods. The course will emphasize connections to real-world applications including machine learning, networking, and finance. The course will involve lectures, homework, exams, and a project. This course is crosslisted with 18660. Although students in 18460 will share lectures with students in 18660, students in 18460 will receive distinct homework assignments, distinct design problems, and distinct exams from the ones given to students in 18660. Specifically, the homework assignments, design problems and exams that are given to the 18660 students will be more challenging than those given to the 18460 students.
Prerequisites: (18-202 Min. grade C or 21-259 Min. grade C or 21-254 Min. grade C or 21-260 Min. grade C) and (36-219 Min. grade C or 36-225 Min. grade C or 36-218 Min. grade C or 21-325 Min. grade C) and 21-241 Min. grade C

18-461 Introduction to Machine Learning for Engineers

Fall and Spring: 12 units
This course provides an introduction to machine learning with a special focus on engineering applications. The course starts with a mathematical background required for machine learning and covers approaches for supervised learning (linear models, kernel methods, decision trees, neural networks) and unsupervised learning (clustering, dimensionality reduction), as well as theoretical foundations of machine learning (learning theory, optimization). Evaluation will consist of mathematical problem sets and programming projects targeting real-world engineering applications. This course is crosslisted with 18661. ECE graduate students will be prioritized for 18661, and ECE undergraduate students will be prioritized for 18461. Although students in 18461 will share lectures with students in 18661, students in 18461 will receive distinct homework assignments, distinct programming projects, and distinct exams from the ones given to students in 18661. Specifically, the homework assignments, programming projects, and exams that are given to the 18661 students will be more challenging than those given to the 18461 students.
Prerequisites: 18-202 Min. grade C and 21-127 Min. grade C and 15-122 Min. grade C and (36-218 Min. grade C or 36-219 Min. grade C or 36-225 Min. grade C or 21-325 Min. grade C)

18-462 Principles and Engineering Applications of AI

Spring: 12 units
This is a first-year graduate course in Principles and Engineering Applications of AI. The course will review the basic principles of AI. Some of the specific topics that will be covered are the following: 1) Intelligent Agents; 2) Single-Agents and Multi-Agent Systems (MAS); 3) Uncertain Knowledge and Reasoning (Probabilistic Reasoning and Probabilistic Reasoning over Time, Bayesian Networks, Dynamic Bayesian Networks, Hidden Markov Models, Kalman Filters, MCMC algorithms, etc.); 4) Learning; 5) Communicating, Perceiving, and Acting; 6) Robotics. The course will involve completing a set of challenging engineering applications of AI that will include: Medical applications, Video Games, Autonomous driving, Autonomous Robots, Finance and Economics, Military, Art, Advertising. Students should have a good background in basic probability theory, maturity in mathematical topics, and good programming skills. For seniors who would like to take the course but do not have the necessary prerequisites, instructor's permission will be required. Although students in 18462 will share lectures with students in 18662, students in 18462 will receive distinct homework assignments, distinct projects, and distinct exams from the ones given to students in 18662. Specifically, the homework assignments, projects, and exams that are given to the 18662 students will be more challenging than those given to the 18462 students.
Prerequisites: 18-751 Min. grade B or 36-218 Min. grade B or 36-219 Min. grade B

18-464 ULSI Technology Status and Roadmap for System on Chips and System in Package

Fall and Spring: 12 units
This course will provide the necessary background for the state-of-the art technologies utilized by the leading edge products covering full spectrum of market drivers from mobile platforms, microprocessors, game chips to the highest performance systems for enterprise solutions computing. We will present all key components of such systems, i.e., logic, analog/RF and embedded memories. Then we present the technology roadmap for the upcoming generations in terms of device architecture options for logic devices (FinFET, Nanowire and Tunnel FET) and memories (Phase Change Memory , Resistive RAM and Magnetic RAM/Spin-Transfer Torque RAM) from the device level all the way to the system level specifications. The last part of the class will be devoted to the system integration issues, namely 3-dimensional integration approaches. This course is designed for MS and PhD students from diverse areas: System/Hardware Design, Circuits and Devices/Nanofabrication and is aimed at bridging the gap among these areas.
Prerequisites: 18-422 or 18-320

18-465 Advanced Probability & Statistics for Engineers

Spring: 12 units
This course will help masters and undergraduate students to obtain the background necessary for excelling in courses and careers in machine learning, artificial intelligence, and related fields. We will cover basic concepts of probability prerequisite to understanding the material typically taught in a ML course. We will also cover slightly more advanced topics including Markov Chains, hypothesis testing, and maximum-likelihood estimation. The remaining part of the semester will be devoted to introducing machine learning concepts such as supervised/unsupervised learning, model identification, clustering, expectation maximization, etc. Students should be familiar with basic calculus, linear algebra. Although students in 18465 will share lectures with students in 18665, students in 18465 will receive distinct homework assignments, distinct projects, and distinct exams from the ones given to students in 18665. Specifically, the homework assignments, projects, and exams that are given to the 18665 students will be more challenging than those given to the 18465 students.

18-469 Special Topics in Integrated Systems Technology

Fall and Spring: 12 units
Please refer to the ECE website for topic descriptions.

Course Website: https://courses.ece.cmu.edu/

18-474 Embedded Control Systems

Spring: 12 units
This course introduces principles for design of embedded controllers. In applications ranging from airplanes, to automobiles, to manufacturing systems, embedded computers now close feedback loops that were previously closed by mechanical devices or by humans in the loop. This course emphasizes practical insight into the tools for modeling and simulating these dynamic physical systems, and methods for designing the real-time software for embedded computers to control them. Lectures cover relevant theory and background from real-time systems and control engineering, including event-based and clock-based sampling, switching control, PWM (pulse-width modulation), PID (proportional-integral-derivative) design, state-variable feedback, state estimation, and methods for setpoint control and trajectory tracking. Basic embedded computing, sensor, and actuator technologies are reviewed, including microcontrollers, DC motors and optical encoders. In the laboratory, students use commercial tools for simulation and automatic code generation to design and implement embedded control system experiments. 3 hrs. lecture, 3 hrs. lab.
Prerequisites: (15-213 or 18-213) and (18-396 or 18-290 or 18-370)

18-482 Telecommunications Technology and Policy for the Internet Age

Spring: 12 units
Modern telecommunications is the nervous system of society. The Internet and wireless communications have transformed every aspect of our modern life. This course provides a comprehensive introduction to basic principles of telecommunications technology and the legal, economic, and regulatory environment of today's networks. Topics covered include the fundamentals of communication network technologies, including video, voice, and data networks; the rising dominance of wireless networks; principles behind telecommunications regulation from common carrier law and natural monopoly to information diversity, privacy and national security; traffic differentiation on the Internet and the debate over network neutrality; universal service and the digital divide; mergers, antitrust, and the changing industrial structure of the communications sector. We will explore current topical questions such as the future of competition; the shift of entertainment video from cable and satellite to Internet delivery; how cloud computing concepts are transforming networks; and communications support for the Internet of Things. Comparison with European approaches to communications regulation. Special emphasis on how new technologies have altered, and are altered by, regulation. Junior, Senior or graduate standing required.
Prerequisite: 73-102

18-487 Introduction to Computer Security

Fall: 12 units
Security is becoming one of the core requirements in the design of critical systems. This course will introduce students to the intro-level fundamental knowledge of computer security and applied cryptography. Students will learn the basic concepts in computer security including software vulnerability analysis and defense, networking and wireless security, and applied cryptography. Students will also learn the fundamental methodology for how to design and analyze security critical systems. Anti-requisites: 18-631 and 18-730
Prerequisite: 18-213

18-490 Electroacoustics

Fall: 12 units
This course provides an introduction to physical, engineering, and architectural acoustics. The course begins with a review of the wave equation and some of its solutions that are relevant to the propagation of sound from planar and spherical sources, and from arrays of simple sources. Lumped-parameter electrical circuit analogies are developed to describe mechanical and acoustical systems, leading to a discussion of the constraints and tradeoffs involved in the design of loudspeakers, microphones, and other transducers. The characteristics of sound in regular and irregular enclosures will be developed and discussed in the context of the acoustical design for rooms and auditoriums. The interaction of sound and man is also discussed, with introductory lectures on auditory perception and the acoustics of speech production, with applications in the areas of efficient perceptually-based coding of music and speech, and virtual acoustical environments.
Prerequisites: 18-220 Min. grade C and 18-290 Min. grade C

18-491 Digital Signal Processing

Spring: 12 units
This course addresses the mathematics, implementation, design and application of the digital signal processing algorithms widely used in areas such as multimedia telecommunications and speech and image processing. Topics include discrete-time signals and systems, discrete-time Fourier transforms and Z-transforms, discrete Fourier transforms and fast Fourier transforms, digital filter design and implementation, and multi-rate signal processing. The course will include introductory discussions of 2-dimensional signal processing, linear prediction, adaptive filtering, and selected application areas. Classroom lectures are supplemented with implementation exercises using MATLAB. Students in 18491 and 18691 will share the same lectures and recitations. Nevertheless, students receiving credit for 18691 will be required to complete an additional capstone project at the end of the semester. Students in 18691 may have additional homework problems on a weekly basis.
Prerequisite: 18-290 Min. grade C

18-495 Speech Technology for Conversational AI

Intermittent: 12 units
This course provides both practical and theoretical knowledge on how we can leverage speech processing technologies to build a conversational AI system. The course encompasses speech recognition, speaker recognition, speech synthesis, speech enhancement, speech translation, spoken dialogue systems, speech foundation models, and other speech and audio processing tasks. In practical sessions, students will learn to build functional speech recognition and synthesis systems or utilize existing large speech and language models and integrate them to create a speech interface using existing toolkits. The course will also present details of algorithms, techniques, evaluation metrics, and limitations of state-of-the-art speech systems. This course is particularly designed for students who want to learn how to process actual data for real-world applications, applying AI and machine learning techniques while also being aware of the current technology limitations.
Prerequisite: 15-211 Min. grade B

18-499 Summer Internship

All Semesters
The Department of Electrical and Computer Engineering at Carnegie Mellon considers experiential learning opportunities important educational options for its undergraduate students. One such option is an internship, normally completed during the summer. Students do not need to officially register for an internship unless they want it listed on their official transcripts. ECE students interested in registering their internship for course credit on their transcript may request to be enrolled in this course. The ECE Undergraduate Office will add the course to the student's schedule, and the student will be assessed tuition for 3 units. This process should be used by international students interested in Curricular Practical Training (CPT) or by any other engineering undergraduate wishing to have their internship experience reflected on their official University transcript. International students should also be authorized by the Office of International Education (OIE). More information regarding CPT is available on OIE's website.

18-500 ECE Design Experience

Fall and Spring: 12 units
The ECE Design Experience is a capstone design course that serves to introduce students to broad- based, practical engineering design and applications through an open-ended design problem. Students will work with a team on a project of their choosing (subject to instructor approval) throughout the semester culminating with a final project presentation, report, and public demonstration. The projects will need to encompass a minimum of two ECE areas. Throughout the semester, teams will need to give both written and oral project proposals and periodic performance updates. Team-building experiences designed to educate students on group dynamics, resource management, deadline planning, Big-picture implications of engineering applications: societal, human, ethical, and long-term impact will be explored. Please note that the full prerequisite list of "All ECE Core Courses plus any two 18-xxx ECE Area Courses" is too long to be put into the registration system. As a result ALL students will be waitlisted for 18-500. Students will be registered once it has been confirmed they have completed the prerequisites, after final grades for the preceding semester.

18-540 Rapid Prototyping of Computer Systems

Spring: 12 units
This is a project-oriented course which will deal with all four aspects of project development; the application, the artifact, the computer-aided design environment, and the physical prototyping facilities. The class, in conjunction with the instructors, will develop specifications for a mobile computer to assist in inspection and maintenance. The application will be partitioned between human computer interaction, electronics, industrial design, mechanical, and software components. The class will be divided into groups to specify, design, and implement the various subsystems. The goal is to produce a working hardware/software prototype of the system and to evaluate the user acceptability of the system. We will also monitor our progress in the design process by capturing our design escapes (errors) with the Orthogonal Defect Classification (ODC). Upon completion of this course the student will be able to: generate systems specifications from a perceived need; partition functionality between hardware and software; produce interface specifications for a system composed of numerous subsystems; use computer-aided design tools; fabricate, integrate, and debug a hardware/software system; and evaluate the system in the context of an end user application. Senior standing is required. This course is crosslisted as 18745
Prerequisites: (18-491 Min. grade C or 18-370 Min. grade C or 18-320 Min. grade C) and (18-349 Min. grade C or 18-341 Min. grade C or 18-340 Min. grade C) and 18-213 and 18-220 and 18-240 and 18-290

18-555 Entrepreneurial Engineering Project

Fall and Spring: 12 units
In this course, Undergraduate (18555) and MS (18655) students participate in projects to develop exploratory designs of systems for a wide range of applications. Each project is unique to a team of students who will typically be paired with an external investment partner. All the projects will be designed, developed, and led by students. Entry into the course is by invitation from the faculty instructor (typically advised by the external investment partners). Student teams will be invited based on the alignment of their skill sets and experience with a set of posted projects. Teams may also be invited based on a student-initiated pitch of their own ideas and its alignment with external investor interest. Students interested in the course can indicate their interest, qualifications, and project ideas via instructions from departmental advisors or the course instructor. Grades will be assigned by the faculty instructor based on novelty and creativity of the project, engineering process, and weekly progress, not the ultimate success or failure of the project idea or originally proposed solution. Following completion of the course, the external investment partners and students can independently explore subsequent seed funding and/or licensing of successful ideas and projects.

18-570 Summer Undergraduate Student-Directed Projects

Summer
Student-directed projects may be available in the summer semester only, allowing a student to explore a topic of their choosing. Students are responsible for pursuing such an option with a faculty member. Enrollment in 18570 precludes earning pay or research credit and requires completing a directed study agreement.

18-578 Mechatronic Design

Spring: 12 units
Mechatronics is the synergistic integration of mechanism, electronics, and computer control to achieve a functional system. Because of the emphasis upon integration, this course will center around system integration in which small teams of students will configure, design, and implement a succession of mechatronic subsystems, leading to a main project. Lectures will complement the laboratory experience with comparative surveys, operational principles, and integrated design issues associated with the spectrum of mechanism, electronics, and control components. Class lectures will cover topics intended to complement the laboratory work, including mechanisms, actuators, motor drives, sensors and electronic interfaces, microcontroller hardware and programming and basic controls. During the first week of class, each student will be asked to complete a questionnaire about their technical background. The class will then be divided into multi-disciplinary teams of three students. During the first half of the class, lab assignments will be made every 1-2 weeks to construct useful subsystems based on material learned in lecture. The lab assignments are geared to build to the main project. This course is cross-listed as 16-778 and 24-778. Students in other departments may take the course upon availability of slots with permission of instructor. Non ECE students may take the course upon availability of slots with permission of the instructor.
Prerequisites: (18-348 and 18-320) or (15-313 and 18-348) or (18-370 and 18-348) or (18-370 and 18-349) or (18-349 and 15-313) or (18-349 and 18-320) or (18-370 and 18-320)

18-580 Undergraduate Projects

All Semesters
The Department of Electrical and Computer Engineering at Carnegie Mellon considers experiential learning opportunities to be important educational options for its undergraduate students. One such option is conducting an undergraduate-level project with a faculty member. Students may work on projects for pay or may register for units of 18580 if they want the course listed on their official transcript. To enroll, the student should first complete the online application for their project on the ECE Student Project Tracker website. Once the application has been submitted and approved by the faculty member on whose project the student is working, the ECE Advising Team will add the appropriate units to the student's schedule. Typically, credit is granted according to one hour of research per week is equal to one unit of credit

18-591 ECE Teaching Assistant Experience

Fall and Spring
Students must complete the online Teaching Assistant application to be considered for a position. TAs can expect to work 10-12 hours per week on average. See https://www.ece.cmu.edu/insider/teaching-opportunities.html for further information about applying for a Teaching Assistant position.

18-614 Microelectromechanical Systems

Fall: 12 units
This course introduces fabrication and design fundamentals for Microelectromechanical Systems (MEMS): on-chip sensor and actuator systems having micron-scale dimensions. Basic principles covered include microstructure fabrication, mechanics of silicon and thin-film materials, electrostatic force, capacitive motion detection, fluidic damping, piezoelectricity, piezoresistivity, and thermal micromechanics. Applications covered include pressure sensors, micromirror displays, accelerometers, and gas microsensors. Grades are based on exams and homework assignments. 4 hrs. lec.
Prerequisites: 18-320 Min. grade C or 24-351 Min. grade C or 18-300 Min. grade C or 18-310 Min. grade C

18-681 Power Electronics

Fall: 12 units
This course is aimed at developing Power Electronics expertise in Masters level students to develop knowledge and skills necessary for the formation of a power electronics engineer. Considerations of static and dynamic characteristics of power semiconductor devices including thermal management are followed by the analysis and design of principal types of power converters. Key applications are also considered so that the course provides a broad knowledge and skills in the field of power electronics in wide ranging applications. Assessment is based on assignments and examinations. It is assumed that students will have an understanding of electrical and amp; electronic principles, power systems, and electrical machines. Content includes: Power Semiconductor Devices Static and Dynamic Characteristics; Application of semiconductor devices and components in the medium to high voltage environment: Series and parallel operation, damping components; Spread of device characteristics, Thermal Management; Naturally commutated converters: Single phase and three phase up to 12 pulse, analysis and operation; Effect of supply side reactance; Grid applications; DC-DC Converters and energy storage: step up and step down operation, application to electric vehicles, battery management and PV systems; Self-commutated converters; Pulsewidth modulation; Multilevel converters; HVDC light; Voltage source converter based HVDC; AC to AC Converters: grid applications.

18-866 Off-Grid Electricity Systems

Spring: 6 units
Over one billion people in the world still lack access to electricity, many of them out of reach of the electricity grid in the near term. This course will explore the technologies and architectures used to provide electricity services in off-grid regions of the developing world. Basic system design principles will be discussed and applied. Students will use energy modeling software to characterize the performance and economic viability of off-grid electricity systems. In addition to studying off-grid technologies, the course will also explore the context in which these systems are deployed and their role in enabling development.

18-867 Applied Smart Grid Telecoms

Spring: 6 units
This course examines applications of standards for communications protocols in smart grids, covering relevant standards such as IEC61850 and DNP3. Participants will complete assignments based on real world examples that explore the implementation and limitations of smart grids telecommunications. Appropriate for communications engineers wanting to understand the power grid, and power engineers wanting to develop their applied knowledge of communications.

18-883 Special Topics in Energy Systems

Fall and Spring: 6 units
Please see the ECE website for a full course description describing the sections of this course. https://courses.ece.cmu.edu/

Department of Engineering and Public Policy

Peter Adams, Department Head

Deanna H. Matthews, Associate Department Head for Undergraduate Affairs

Location: Wean Hall 4101
www.cmu.edu/epp (http://www.cmu.edu/epp/)

The Department of Engineering and Public Policy (EPP) is a unique department that works on problems at the interface between technology and society. Society is largely responsible for setting the goals and framing the problems that engineers and scientists work on. However, technologies designed by engineers and scientists profoundly change the societies in which they operate. Technology has enabled a healthier, richer, and more productive society. At the same time, technology has contributed to the creation of many of the more serious problems our society faces. In order to do their jobs responsibly and well in today's world, engineers and scientists must develop an understanding of the interface between technology and society and a command of the skills necessary to work at that interface. Our undergraduate programs aim to educate young scholars to be interdisciplinary problem solvers.

The undergraduate degree programs of the Department of Engineering and Public Policy (EPP) have been designed to allow undergraduate students at Carnegie Mellon University to add this important interdisciplinary dimension to their traditional engineering or science education. Our additional major graduates, for the most part, will enter traditional engineering or science careers, but will carry with them a set of insights and skills that will help them to better deal with issues in technology and policy, and better exercise their ethical and social obligations as practicing professionals. Our program has a long history of 50+ years producing graduates with these critical skills, with alumni serving in all areas of industry and government.

Overview of Our Undergraduate Programs

The undergraduate additional major programs in EPP combine the strong foundation in mathematics and physical sciences, and the development of engineering or science skills with a rigorous preparation in the analysis of social and political problems. The curriculum includes subject matter which is not part of traditional technical or social science curricula, but which contains elements of each. Students complete courses in four core areas: economics, statistics, decision-making, and communication. Breadth is achieved through EPP Technology-Policy elective courses. Finally, students apply their skills in a project preparatory course and two interdisciplinary problem-solving projects. Problem areas for these projects are chosen from local, state, and national situations, and include such topics as climate change, energy systems, technological innovation, telecommunication issues, computer security and privacy, risk analysis and communication, among others. Students from several CMU colleges enroll in these projects courses exposing EPP additional majors to working in truly interdisciplinary situations. Examples of past project course topics (http://www.cmu.edu/epp/prospective/undergraduate/epp-project-courses/) and final reports are available.

Additional Major in Engineering and Public Policy

The EPP department offers an additional major in Engineering and Public Policy (EPP) for students completing an undergraduate degree in engineering from any of the five traditional engineering departments in the engineering college. The engineering additional major leads to a fully accredited engineering degree that prepares students for traditional technical careers. EPP additional major engineers are not educated to be a different kind of engineer. Rather, their education is intended to enable them to be better, more socially responsible engineers in the traditional technical fields.

Additional Major in Science, Technology, and Public Policy

The EPP department offers an additional major in Science, Technology and Public Policy (STPP) for students completing an undergraduate B.S. degree outside of the engineering college. This includes students in the Mellon College of Science, the School of Computer Science, Tepper School of Business, and select majors in the Dietrich College and College of Fine Arts. Similar to the additional major in Engineering and Public Policy, the additional major in Science, Technology and Public Policy is meant to broaden the perspectives on a student’s primary major and provide additional skills for future careers.

Minor in Technology and Policy

The department also offers a minor in Technology and Policy. The Technology and Policy minor exposes students to issues at the interface of science, technology, and society, and how interdisciplinary approaches are needed to solve complex problems.

Minor in Information Security, Privacy and Policy

The department offers a minor in Information Security, Privacy and Policy for all majors in partnership with the School of Computer Science. The Information Security, Privacy and Policy minor offers students an understanding of how to identify potential security and privacy risks and relevant legal and policy issues; a working understanding of security topics as they pertain to design, development and management of new information technologies.

Career Options with OUR Additional Majors

Students who select one of the our additional majors graduate with an accredited engineering degree or complete science degree, and thus have all of the options for traditional technical careers as their single major classmates. A large portion of our additional major students pursue traditional technical careers after graduation in areas such as product development, consulting, project management, etc.

The advantage of the additional major is the added set of skills and perspectives, which allow a graduate of the program to improve the quality, sensitivity, and social responsiveness of their work, and the work of their colleagues. Employers recognize these skills and often view our graduates as more attractive for a traditional engineering or technical position. Firms contact the EPP department every year to recruit EPP graduates because of their satisfaction with the knowledge and skills acquired by EPP students. In addition, the additional major also opens up options for careers in policy analysis in federal, state, and local government or in public policy consulting firms. Alumni pursue careers in a range of companies to deal with issues like government regulation of technological systems, climate change impacts, product liability and safety, environmental control, telecommunications policy, energy systems, financial investment, and the social impact of large technological systems.

Students also choose to continue their formal education, doing graduate work in engineering, the social sciences, law, or interdisciplinary programs.

Faculty Advisors

Faculty in several departments serve as advisors and information resources to students selecting the EPP undergraduate programs. Given the interdisciplinary perspective of EPP, students may find that a faculty member outside their traditional major can provide support and guidance with EPP-related courses and career paths. The EPP Associate Department Head for Undergraduate Affairs is Deanna Matthews. Dr. Matthews can provide general academic advice and guidance for all EPP undergraduates. Other faculty affiliated with the undergraduate programs in EPP are:

- Civil Engineering: Peter Adams, Destenie Nock
- Chemical Engineering: Peter Adams, Neil Donahue
- Economics/Business: Nicholas Muller, Marvin Sirbu, Phillip Yu
- Electrical and Computer Engineering: Jon Peha, Ramteem Sioshansi, Marvin Sirbu
- Engineering and Public Policy: Doron Cohen, Erica Fuchs, Paulina Jaramillo, Valerie Karplus, Deanna Matthews, Granger Morgan
- Institute for Strategy and Technology: Baruch Fischhoff
- Mechanical Engineering: Jeremy Michalek, Kate Whitefoot
- Material Science and Engineering: Jay Whitacre
- Software, Systems, and Society Department: Lorrie Cranor, Nicolas Christin, Sarah Scheffler

EPP Program Educational Objectives

The additional major in Engineering and Public Policy is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org.

Students who earn an additional major in Engineering and Public Policy at the undergraduate level do so in conjunction with a traditional engineering major. The elements of the EPP undergraduate program broaden the traditional scope of technical analysis to encompass an engineering solution's potential impact on society. Thus, our graduates have all of the skills as their peers in traditional engineering majors, but with a broader societal perspective and additional analysis skills. This enables our graduates:

- to understand the interface between technology and society and
- to help solve the complex, interdisciplinary systems problems facing our world in their careers.

Students will be able to work in a variety of career fields, including technical and non-technical, in industry, government or elsewhere where these broad skills are needed.

EPP Student Outcomes

By the end of the combined B.S. programs in a traditional engineering program and the EPP program, students should have attained the following:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Course Requirements for the Additional Major in EPP

Minimum units for the additional major 106

Students pursuing an additional major in EPP must complete three sets of requirements: courses for the EPP additional major, courses for their traditional engineering major, and general education courses. The student should refer to the relevant sections of this catalog for the required courses in the traditional engineering major. The EPP additional major is designed to be completed with a traditional engineering major in the standard eight-semester time frame. However, additional units or course work may be required. Some courses for the EPP additional major may also satisfy requirements for traditional engineering courses or for general education courses.

Overview

Course		Units
19-101	Introduction to Engineering and Public Policy	12
19-201	Professional Issues in Engineering, Science, Technology and Public Policy	1
73-102	Principles of Microeconomics	9
36-220	Engineering Statistics and Quality Control	9
(or other approved statistics course)		
19-301	Decision Making Methods for Engineers and Scientists	9
or 19-469	Behavior, Decision and Policy	
or 84-369	Decision Science for International Relations	
or 88-223	Decision Analysis	
(or other approved decision science course)		
76-270	Writing for the Professions	9
(or other approved writing course)		
19-351	Applied Methods for Technology-Policy Analysis	9
19-451	EPP Projects I	12
19-452	EPP Projects II	12
Three EPP Technology-Policy Electives		min. 24

Introductory Courses

		Units
19-101	Introduction to Engineering and Public Policy	12
19-201	Professional Issues in Engineering, Science, Technology and Public Policy	1

The two introductory courses prepare students for the additional major experience through discussion and assessment of technology-policy interactions. 19-101 Introduction to Engineering and Public Policy may be taken as the second introductory engineering course for engineering students. 19-201 Professional Issues in Engineering, Science, Technology and Public Policy is required in addition to any corresponding seminar course in a student's traditional degree program.

Core Area Courses

73-102	Principles of Microeconomics	9
EPP Statistics elective - one of the following, or other approved course:		
36-220	Engineering Statistics and Quality Control	9
EPP Decision Science elective - one of the following, or other approved course (9 units minimum):		
19-301	Decision Making Methods for Engineers and Scientists	9
19-469	Behavior, Decision and Policy	9
84-369	Decision Science for International Relations	9
88-223	Decision Analysis	12
EPP Writing and Communications elective - one of the following, or other approved course		
76-270	Writing for the Professions	9

The four core area courses provide the foundational skills in the social sciences that are needed for robust analysis of policy problems. 73-102 Principles of Microeconomics fulfills a CIT General Education course. Students who receive a pre-requisite waiver for 73-102 may take a higher-level economics course as a substitute with approval.

CivE, EnvE, MechE, and MSE students will complete the statistics elective as part of their traditional engineering majors. ChemE students will substitute the statistics elective for the Advanced Chemistry Elective. ECE students, who have a required course in probability for their traditional engineering major are encouraged to take 36-226 Introduction to Statistical Inference to fulfill the EPP statistics requirement. Students should complete the statistics requirement by the end of sophomore year. A statistics course is a prerequisite for the EPP Decision Science elective.

The EPP Decision Science elective fulfills either the CIT General Education Social Analysis and Decision Making requirement or a CIT General Education free elective. The EPP Writing and Communications course fulfills the CIT General Education Writing and Expressions requirement.

Technology-Policy Electives

- At least 3 courses of EPP Technology-Policy electives (24 units minimum)

EPP Technology-Policy Electives include courses that belong to three categories. First, EPP Technology-Policy Electives include courses that synthesize engineering analysis and social analysis perspectives and apply them to problems with substantial societal and technological components. Specific areas of interest for these courses are (1) energy, resources, and the environment, (2) risk assessment, (3) technology innovation, (4) urban engineering, (5) information and communication technology, and (6) product engineering and design, among others. Second, EPP Technology-Policy Electives include courses that teach methods or analysis skills necessary for solving complex problems. Examples include mathematical or statistical courses related to optimization or estimation, or economics courses related to economic analysis. Finally, EPP Technology-Policy Electives include courses that provide technical background for policy relevant issues. These courses are fundamental for understanding our current engineering systems and how proposed changes can be implemented. Examples include courses on electricity systems, engine design, or atmospheric systems. A sample of courses for EPP Technology-Policy Electives is below, a full list of approved courses is available from the department.

19-211	Ethics and Policy Issues in Computing	9
19-303	Cryptocurrencies, Blockchains and Applications	Var.
19-403	Policies of Wireless Systems	12
19-411	Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech	9
19-425	Sustainable Energy for the Developing World	9

19-429	Climate Change Science and Solutions	9
19-433	Data Science for Technology, Innovation and Policy	9
19-608	Privacy Policy, Law, and Technology	12
19-668	Electric Vehicles: Technology, Economics, Environment and Policy	12

The majority of 19-xxx EPP departmental courses are considered EPP Technology-Policy Electives. Exceptions will be identified when the courses are offered. Courses that are required or used for core area courses for the additional major can not be used as electives. Courses from other departments also are acceptable as electives with approval. Students should work with their advisors to define areas of concentration or a selection of breadth courses for the EPP Technology-Policy Electives.

Students are required to take at least three EPP Technology-Policy electives for a minimum of 24 units. Units may be added in any combination, but a maximum of one 3-unit course is permitted. Up to 9 units of 19-550 Undergraduate Research may be used with approval. Students may not use a required course from their traditional engineering major for these elective units. However, students may use an elective course from their traditional major requirements to meet the requirements of both their traditional engineering major and an EPP Technology-Policy elective, but the units for the course will not be double-counted toward units required for their degree. Some EPP Technology-Policy elective courses may fulfill requirements for CIT General Education categories (e.g., 19-411 Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech is an I&I course), otherwise students use Free Elective units to complete this requirement.

Capstone Courses

		Units
19-351	Applied Methods for Technology-Policy Analysis	9
19-451	EPP Projects I	12
19-452	EPP Projects II	12

The capstone courses synthesize the technical skills and knowledge from a student’s traditional major with the social science skills and broad perspective of the EPP major.

19-351 Applied Methods for Technology-Policy Analysis is a preparatory course for EPP Projects sequence. 19-351 may be completed as a co-requisite of 19-451 EPP Projects I. The course fulfills CIT General Education elective units.

19-451 EPP Projects I and 19-452 EPP Projects II are technology/policy projects which deal with research and development of recommendations for solving actual and critical problems currently affecting society. The students, faculty, and graduate student managers for the project are drawn from EPP, Social and Decision Sciences, and the Heinz College, and other CMU departments, and hence bring different areas of expertise to the structuring and solution of the problem. The topics for EPP Projects are drawn from diverse areas such as environmental systems and resources, public transportation, urban engineering problems, energy and fuel utilization, the interaction of law and technology, strategic materials and vulnerability of supply, technical issues in national security, and problems in automation, robotics, and communication technology. Students use Free Elective units to complete this requirement. 19-452 EPP Projects II serves as the capstone engineering design course experience for additional majors.

Notes on EPP additional major requirements

Students should follow the suggested curriculum timelines for completing the math, science, and engineering course requirements of the traditional major with the exception of the statistics elective which should be taken as early as possible and no later then the end of sophomore year.

Some courses as noted above may be used to fulfill requirements of general education courses. Acceptable courses for the CIT General Education requirements are maintained by the CIT Dean's Office. Students must submit a plan during their first-semester as an EPP student (usually Fall sophomore year) for these general education courses demonstrating their relevance to EPP.

Students must complete the minimum number of units as required by their traditional major for graduation. In some cases, students completing the EPP additional major may need to complete additional units to meet all requirements for the traditional major and EPP additional major.

In addition to any other graduation requirements (e.g., regarding course work, minimum QPA, pass/fail course work, etc.) of the student's traditional disciplinary major, students must earn a minimum QPA of 2.0 in all courses required for the EPP major.

Side-by-side curriculum charts (http://www.cmu.edu/epp/prospective/undergraduate/epp-additional-major/curriculum-charts/) of the curricula for the traditional engineering majors alone versus the traditional engineering majors with the EPP additional major can assist students in determining the course requirements and scheduling needed to complete the degree requirements.

A proposed semester plan is below. Students work with their advisors to determine the best sequence of courses given the varied requirements in the traditional engineering majors.

Course	Semester
19-101 Introduction to Engineering and Public Policy	**First-year Spring**
73-102 Principles of Mircoeconomics	**First-year Fall or Spring**
19-201 Professional Issues in Engineering, Science, Technology and Policy	**Sophomore Fall**
EPP Statistics Elective	**Sophomore Fall or Spring**
EPP Writing and Communications Elective	**Sophomore Fall or Spring**
EPP Decision Science Elective	**Junior Fall**
19-351 Applied Methods for Technology-Policy Analysis	**Junior Spring**
3 EPP Technology-Policy Electives	**Junior and/or Senior year**
19-451 / 19-452 EPP Projects I and II	**Senior Fall and Spring**

Course Requirements for the Additional Major in STPP

Minimum units required for additional major 106

Students pursuing an additional major in STPP must complete three sets of requirements: courses for the STPP additional major, courses for their traditional disciplinary major, and general education courses. The student should refer to the relevant sections of this catalog for the required courses in the traditional disciplinary major. The STPP additional major is designed to be completed with a traditional disciplinary major in the standard eight-semester time frame. However, additional units or course work may be required. Some courses for the STPP additional major may also satisfy requirements for traditional disciplinary majors or for general education courses.

Introductory Courses

		Units
19-101	Introduction to Engineering and Public Policy	12
19-201	Professional Issues in Engineering, Science, Technology and Public Policy	1

The two introductory courses prepare students for the additional major experience through discussion and assessment of technology-policy interactions. 19-101 Introduction to Engineering and Public Policy may qualify as a general education course in some majors. 19-201 Professional Issues in Engineering, Science, Technology and Public Policy is required in addition to any corresponding seminar course in a student’s traditional degree program.

Core Area Courses

73-102	Principles of Microeconomics	9
Statistics course — one of the following:		
36-220	Engineering Statistics and Quality Control	9
36-226	Introduction to Statistical Inference	9
or other approved statistics course		
STPP Decision Science course — one of the following:		
19-301	Decision Making Methods for Engineers and Scientists	9
19-469	Behavior, Decision and Policy	9
84-369	Decision Science for International Relations	9
88-223	Decision Analysis	12
88-302	Behavioral Decision Making	9
or other approved decision science course		
STPP Writing and Communications course — one of the following:		
76-270	Writing for the Professions	9

76-271	Introduction to Professional and Technical Writing	9
or other approved writing and communications course		

The four core area courses provide the foundational skills in the social sciences that are needed for robust analysis of policy problems. For students in SCS and MCS, the economics, decision science, and writing course selections may qualify as general education courses, and the statistics elective may qualify for a math/science requirement. For students in DC and CFA, some core area requirements may be fulfilled by traditional program requirements or general education courses. Students should consult with their advisors in both programs to assure that courses are meeting requirements and providing appropriate depth of content. Students who receive a pre-requisite waiver for 73-102 may complete a higher-level economics course as a substitute with approval.

Technology-Policy Electives

3 courses	**24 minimum units**

STPP Technology-Policy Electives include courses that belong to three categories. First, STPP Technology-Policy Electives include courses that synthesize technical analysis and social analysis perspectives and apply them to problems with substantial societal and technological components. Specific areas of interest for these courses are (1) energy, resources, and the environment, (2) risk assessment, (3) technology innovation, (4) urban engineering, (5) information and communication technology, and (6) product development and design, among others. Second, STPP Technology-Policy Electives include courses that teach methods or analysis skills necessary for solving complex problems. Examples include mathematical or statistical courses related to optimization or estimation, or economics courses related to economic analysis. Finally, STPP Technology-Policy Electives include courses that provide technical background for policy relevant issues. These courses are fundamental for understanding our current technical systems and how proposed changes can be implemented. Examples include courses on electricity systems, telecommunication systems, engine design, or atmospheric systems. A sample of courses for STPP Technology-Policy Electives is below, a full list of approved courses is available from the department.

19-211	Ethics and Policy Issues in Computing	9
19-303	Cryptocurrencies, Blockchains and Applications	Var.
19-403	Policies of Wireless Systems	12
19-411	Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech	9
19-421	Emerging Energy Policies	9
19-425	Sustainable Energy for the Developing World	9
19-429	Climate Change Science and Solutions	9
19-433	Data Science for Technology, Innovation and Policy	9
19-608	Privacy Policy, Law, and Technology	12
19-668	Electric Vehicles: Technology, Economics, Environment and Policy	12

The majority of 19-xxx EPP departmental courses are considered STPP Technology-Policy Electives. Exceptions will be identified when the courses are offered. Courses that are required or used for core area courses for the additional major can not be used as electives. Courses from other departments also are acceptable as electives with approval. Students should work with their advisors to define areas of concentration or a selection of breadth courses for the STPP Technology-Policy Electives.

Students are required to take at least three STPP Technology-Policy electives for a minimum of 24 units. Units may be added in any combination, but a maximum of one 3-unit course is permitted. Up to 9 units of 19-550 Undergraduate Research may be used with approval. Students may not use a required course from their traditional disciplinary major for these elective units. However, students may use an elective course from their traditional major requirements to meet the requirements of both their traditional engineering major and an STPP Technology-Policy elective, but the units for the course will not be double-counted toward units required for their degree. Some STPP Technology-Policy elective courses may fulfill general education requirements for traditional major programs.

Capstone Courses

19-351	Applied Methods for Technology-Policy Analysis	9
19-451	EPP Projects I	12
19-452	EPP Projects II	12

The capstone courses synthesize the technical skills and knowledge from a student’s traditional major with the social science skills and broad perspective of the STPP additional major.

19-351 Applied Methods for Technology-Policy Analysis is a preparatory course for the EPP Projects sequence. 19-351 may be completed as a co-requisite of 19-451 EPP Projects I.

19-451 EPP Projects I and 19-452 EPP Projects II are technology/policy projects which deal with research and development of recommendations for solving actual and critical problems currently affecting society. The students, faculty, and graduate student managers for the project are drawn from the EPP and STPP programs, Social and Decision Sciences, and the Heinz College, and other CMU departments, and hence bring different areas of expertise to the structuring and solution of the problem. The topics for EPP Projects are drawn from diverse areas such as environmental systems and resources, public transportation, urban engineering problems, energy and fuel utilization, the interaction of law and technology, strategic materials and vulnerability of supply, technical issues in national security, and problems in automation, robotics, and communication technology. These capstone courses may qualify as capstone experience courses or general education courses in some major programs.

Notes on STPP additional major requirements

Students should follow the suggested curriculum timelines for completing the course requirements of their primary major program where necessary and will work with both their primary program advisor and the STPP advisor to assure that requirements for both degrees are met.

Students must complete the minimum number of units as required by their primary major for graduation. In some cases, students completing the STPP additional major may need to complete additional units to meet all requirements for the primary major and STPP additional major.

In addition to any other graduation requirements (e.g., regarding course work, minimum QPA, pass/fail course work, etc.) of the student's primary major, students must earn a minimum QPA of 2.0 in all courses required for the STPP additional major.

Integrated B.S./M.S. Programs

B.S. integrated with M.S. in Engineering and Public Policy

CMU undergraduate students, regardless of whether they complete an undergraduate additional major in EPP or STPP or not, may plan a course of study that leads to completing both their undergraduate B.S. degree and an MS in Engineering and Public Policy. This course of study will ordinarily require two additional semesters of study beyond that required for an undergraduate degree, although advanced placement or other study may reduce this time. Some coursework towards the MS may be completed during the student's senior year, however no courses taken may count for both a BS program and the MS in EPP. Students interested in the program should contact their advisor for details on the application process and course requirements. See the EPP website for more information about the MS in EPP program requirements (https://www.cmu.edu/epp/prospective/ms-in-epp/) including curriculum.

Minors in Engineering and Public Policy

MINOR IN TECHNOLOGY AND POLICY

The department offers a minor in Technology and Policy. This minor allows students to sample the EPP requirements and develop exposure and awareness to issues at the interface of science, technology, and society.

Pre-requisites: Students should have prerequisite knowledge in economics (73-102 Principles of Microeconomics or similar level economics course) and statistics (36-202 Methods for Statistics & Data Science or similar level statistics course) in order to pursue the Technology and Policy Minor.

Course Requirements		Units
19-101	Introduction to Engineering and Public Policy	12
19-301	Decision Making Methods for Engineers and Scientists (or other approved Decision Science course)	9
or 19-351	Applied Methods for Technology-Policy Analysis	
19-451	EPP Projects I	12
xx-xxx	Two EPP Technology-Policy Electives	18

EPP Technical Electives include courses that address problems at the society-technology interface and the means of analyzing these issues. A list of qualifying Technology-Policy electives is available from the EPP Department. Example Technology-Policy electives include:

19-211	Ethics and Policy Issues in Computing	9
19-303	Cryptocurrencies, Blockchains and Applications	Var.
19-403	Policies of Wireless Systems	12
19-411	Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech	9
19-425	Sustainable Energy for the Developing World	9
19-429	Climate Change Science and Solutions	9
19-433	Data Science for Technology, Innovation and Policy	9
19-534	Usable Privacy and Security	9

Students must earn a cumulative QPA of 2.0 in all courses taken for the minor. Required courses taken for a student's primary major may not be counted toward the Technology and Policy Minor. Elective courses for a student's primary major or courses fulfilling general education requirements may be counted, however.

Details of this program are provided in the discussion of CIT minors; see Technology and Policy Minor Description (p.).

MINOR IN INFORMATION SECURITY, PRIVACY AND POLICY

Lujo Bauer, Director

Interdisciplinary minor offered by both CIT and SCS

There is a growing demand for security and privacy experts, and increasing interest among CMU undergraduates in taking security and privacy courses. Security and privacy expertise is an asset in a variety of careers outside, not just in computer science, but also in areas that include business, management, and law. In addition, the policy side of security and privacy is becoming increasingly important and employers are interested in hiring people with an understanding of relevant policy issues, especially in the privacy and security area.

This minor is for undergraduate students across the university who are interested in policy issues related to security and privacy, including those who are planning careers in security/privacy as well as those who plan to focus their careers in other areas. The curriculum has been designed to accommodate students from any major as long as they have taken at least one introductory-level college programming course (such as 15-110 or 15-112).

After completing this minor, students will have a good understanding of how to identify potential security and privacy risks and relevant legal and policy issues; a working understanding of security topics such as cryptography, authentication, and Internet security protocols; as well as broad knowledge of several security- and privacy-related areas as they pertain to the design, development, deployment and management of technologies in a variety of practical contexts (e.g., Web, mobile, Internet of Things, social media, crypto currencies).

Admission

Students are not required to apply to enroll in this minor to start the required courses. However, they are encouraged to consult with the minor director on their elective course selection. In addition, students doing the independent study option must get approval from the minor director prior to enrolling in their independent study course. Finally, students must contact the minor director to certify their completion of the minor.

Curriculum

Students are required to take five courses to complete this minor with a minimum of 48 units.

INTRODUCTORY SECURITY COURSE

17-331	Information Security, Privacy, and Policy	12

Students who have taken 15-213 Introduction to Computer Systems may substitute 15-330 Introduction to Computer Security/18-330 Introduction to Computer Security

PRIVACY AND POLICY COURSE

17-333	Privacy Policy, Law, and Technology	9

Students may substitute 12-unit version of this course: 19-608, 17-733, or 95-818.

PRIVACY ELECTIVES

Complete a minimum of 9 units:		Units
19-534/17-334/05-436	Usable Privacy and Security	9
19-602/17-702	Current Topics In Privacy Seminar	3
17-731	Foundations of Privacy	12

TECHNOLOGY AND POLICY ELECTIVES

Complete a minimum of 9 units:		Units
19-211	Ethics and Policy Issues in Computing	9
17-562	Law of Computer Technology	9
19-101	Introduction to Engineering and Public Policy	12
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-403	Policies of Wireless Systems	12
19-639	Policies of the Internet	12
84-387	Remote Systems and the Cyber Domain in Conflict	9

Crosslisted courses are also allowed.

ADDITIONAL APPROVED ELECTIVE

Students must complete an additional elective of 9 units or more. Students may choose an additional privacy elective or technology policy elective from the list above, or the one of the following security electives:

15-316	Software Foundations of Security and Privacy	9
15-356	Introduction to Cryptography	12
19/17-303	Cryptocurrencies, Blockchains and Applications	Var.
19-534/17-334	Usable Privacy and Security	9
18-334	Network Security	12
18-335	Secure Software Systems	12
18-435	Foundations of Blockchains	12

*Course 18-733 Applied Cryptography is also an approved security elective.

Students who have the necessary prerequisites may choose any approved elective from the SCS or ECE security and privacy undergraduate concentration. Check with the minor program director to determine which category of elective each course will fulfill.

Students should be careful to choose electives for which they have appropriate prerequisites. New elective options are expected as more courses are offered. Students may petition to count a course not on this list as an elective. Students should request permission *before* taking a course that is not on this list. Students may not count multiple electives that overlap substantially.

Optional Project: Subject to approval by the minor director, students may optionally count towards one of the elective requirements 9 units of an independent study or research project course in the security or privacy area, under the supervision of a faculty member in any department. In order to receive credit towards the minor, students must submit a brief project proposal to their project advisor and to the minor director and have it approved prior to conducting the project. Depending on the topic of the project, the minor director may approve credits counting towards privacy electives, technology policy electives, security electives, or some combination of these. Students may work individually, with other undergraduates, or as part of project teams with graduate students or research staff. Students involved in a group project must identify specific project components for which they are responsible. In addition, they must submit a final project report to their project advisor and the minor director that includes a literature review and describes the work they completed. Students working on a group project must each submit their own final report, which should also situate their contribution in the context of the larger project. Note, students are expected to work approximately 1 hour per week for each unit of project in which they are enrolled (e.g. 9 units = 9 hours/week of project work).

Double Counting: At most 2 of the courses used to fulfill the minor requirements may be counted towards any other undergraduate major or minor program. This rule does not apply to courses counted for general education requirements.

Notes on EPP Undergraduate/ Graduate Level Courses

Many courses taught by the department (19-XXX courses) are offered to undergraduate and graduate students. These "dual level" courses are offered in two formats:

- Some courses are taught under both an undergraduate and graduate number. An example is 19-403 Policies of Wireless Systems, also offered as 19-713. In these types of courses, students who sign up under the 700-level (graduate) course number may be expected to perform the same coursework at a higher level, and/or complete additional coursework, compared to 400-level students. Undergraduates who choose to take the course under the graduate number will be also be expected to work at the higher expectation/coursework level.

- Other courses are taught under a 600 level number. An example is 19-668 Electric Vehicles: Technology, Economics, Environment and Policy. These courses may be taken by undergraduates as a senior level course, or by graduate students as a graduate level course. As with dual number courses, graduate level students or undergraduates taking the course for graduate credit may be required to perform coursework at a higher level and/or complete additional coursework. Undergraduates who are taking a 600 level course for graduate credit should identify this fact to both the course instructor and to their EPP department advisor.

Students who have questions about the requirements of a specific EPP 400/700, or 600 level course, should contact the course instructor. Some courses have pre-requisites which may be waived for students given prior background.

Faculty

PETER ADAMS, Thomas Lord Professor of Civil and Environmental Engineering and Engineering and Public Policy / Department Head, Engineering and Public Policy; Professor of Civil and Environmental Engineering / Engineering and Public Policy – Ph.D., Caltech; Carnegie Mellon, 2001–

TIMOTHY BROWN, Professor of Engineering and Public Policy; Director of Research, Carnegie Mellon University Africa – Ph.D., California Institute of Technology; Carnegie Mellon, 2013–

KATHLEEN M. CARLEY, Professor, Software and Societal Systems / Engineering and Public Policy / Social and Decision Sciences / Heinz College of Information Systems and Public Policy / Tepper School of Business – Ph.D., Harvard University; Carnegie Mellon, 1984–

NICOLAS CHRISTIN, Department Head, Software and Societal Systems Department; Professor, Engineering and Public Policy / Software and Societal Systems / CyLab – Ph.D., University of Virginia; Carnegie Mellon, 2005–

DORON COHEN, Assistant Professor, Engineering and Public Policy – PhD, Technion – Israel Institute of Technology; Carnegie Mellon, 2024–

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PEDRO FERREIRA, Professor, Heinz College of Information Systems and Public Policy / Engineering and Public Policy – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2010–

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ERICA R. H. FUCHS, Professor of Engineering and Public Policy – Ph.D., MIT; Carnegie Mellon, 2007–

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VALERIE KARPLUS, Professor of Engineering and Public Policy – PhD, MIT; Carnegie Mellon, 2020–

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JEREMY J. MICHALEK, Professor of Mechanical Engineering / Engineering and Public Policy – Ph.D., University of Michigan; Carnegie Mellon, 2005–

M. GRANGER MORGAN, Hamerschlag University Professor of Engineering, Engineering and Public Policy / Electrical and Computer Engineering / Heinz College of Information Systems and Public Policy – Ph.D., University of California, San Diego; Carnegie Mellon, 1974–

NICHOLAS MULLER, Lester and Judith Lave Professor of Economics, Engineering, and Public Policy, Tepper School of Business / Engineering and Public Policy – Ph.D., Yale University; Carnegie Mellon, 2017–

DESTENIE NOCK, Assistant Professor, Civil and Environmental Engineering/ Engineering and Public Policy – PhD, University of Massachusetts, Amherst; Carnegie Mellon, 2019–

JON M. PEHA, Professor of Engineering and Public Policy – Ph.D., Stanford University; Carnegie Mellon, 1991–

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JEANNE VANBRIESEN, Duquesne Light Company Professor, Professor of Civil and Environmental Engineering / Engineering and Public Policy – Ph.D., Northwestern University; Carnegie Mellon, 1999–

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KATE WHITEFOOT, Associate Professor of Mechanical Engineering / Engineering and Public Policy – Ph.D., University of Michigan; Carnegie Mellon, 2016–

PHILLIP YU, Associate Teaching Professor and Executive Director of Master's Programs, Engineering and Public Policy – PhD, Tufts University; Carnegie Mellon, 2023–

Emeriti Faculty

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ALFRED BLUMSTEIN, J. Erik Jonsson University Professor of Urban Systems and Operations Research; Professor of The H. John Heinz III College / Engineering and Public Policy, Emeritus – Ph.D., Cornell University; Carnegie Mellon, 1969–

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JOEL A. TARR, Richard S. Caliguiri University Professor of Urban and Environmental History and Policy, History/Engineering and Public policy/ Heinz College of Information Systems and Public Policy, Emeritus – Ph.D, Northwestern University; Carnegie Mellon, 1967–

ROBERT M. WHITE, University Professor of Electrical and Computer Engineering / Engineering and Public Policy, Emeritus – Ph.D., Stanford University; Carnegie Mellon, 1993–

Department of Engineering and Public Policy Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

19-101 Introduction to Engineering and Public Policy

Fall and Spring: 12 units
This course examines interactions between technology and society, and the related processes of public and private decision-making. Classes involve a mix of lecture, discussion, and hands-on activities where students tackle interdisciplinary issues with both quantitative and qualitative methods. Students complete individual and group assignments that build skills in analysis and communication relevant for future careers. Past project topics include: using drone imaging to assess algal blooms in Lake Erie, incorporating renewable electricity generation on campus, reducing credit card fraud through data analytics, and creating standards for additive manufacturing of critical airplane parts.

19-201 Professional Issues in Engineering, Science, Technology and Public Policy

Fall: 1 unit
The course provides an overview of the academic and professional domain of technology-centered policy. Content includes career exploration, networking practice, ethics and professional responsibilities, academic advising, alumni speakers, and other topics as relevant. Intended for sophomores enrolling in the Engineering and Public Policy (EPP) Additional Major and the Science, Technology and Public Policy (STPP) Additional Major.

19-211 Ethics and Policy Issues in Computing

Spring: 9 units
Should autonomous robots make life and death decisions on their own? Should we allow them to select a target and launch weapons? To diagnose injuries and perform surgery when human doctors are not around? Who should be permitted to observe you, find out who your friends are, what you do and say with them, what you buy, and where you go? Do social media and personalized search restrict our intellectual horizons? Do we live in polarizing information bubbles, just hearing echoes of what we already know and believe? As computing technology becomes ever more pervasive and sophisticated, we are presented with an escalating barrage of decisions about who, how, when, and for what purposes technology should be used. This course will provide an intellectual framework for discussing these pressing issues of our time, as we shape the technologies that in turn shape us. We will seek insight through reading, discussion, guest lectures, and debates. Students will also undertake an analysis of a relevant issue of their choice, developing their own position, and acquiring the research skills needed to lend depth to their thinking. The course will enhance students' ability to think clearly about contentious technology choices, formulate smart positions, and support their views with winning arguments.

19-213 The American Railroad: Decline and Renaissance in the Age of Deregulation

Intermittent: 6 units
Railroads in the USA are often considered as a subject for nostalgia or public sector failure, an image largely based on passenger service. However, the USA's private sector freight rail industry is considered a model for the world as the result of its renaissance following deregulation in 1980. This is a "stealth" industry whose history and economics are both intertwined and complex. Students will gain a basic understanding of the industry's history and economics and its role in the national transportation network, with special attention to the past half-century. In addition, students will participate in small group research projects in particular areas of special interest - for example, economic history, industry and safety culture, network economics, utility regulation or transportation policy.

19-301 Decision Making Methods for Engineers and Scientists

Fall: 9 units
This course covers various economic, statistical, and decision analysis techniques used for examining complex decisions where technology, society, and policy interconnect. Topics covered include: estimation techniques, benefit-cost analysis, decision trees, dealing with uncertainty, risk perception and analysis, survey design and implementation, utility theory, heuristics and biases in inference and prediction, methods for combining information from different sources and dealing with conflicting objectives.
Prerequisites: 19-250 Min. grade C or 36-219 Min. grade C or 36-220 Min. grade C or 36-217 Min. grade C

19-303 Cryptocurrencies, Blockchains and Applications

Spring: 9 units
Note: Previously offered as 19-355. Cryptocurrencies such as Bitcoin have gained large popularity in recent years, in no small part due to the fantastic potential applications they could facilitate. This course will first provide an overview of the technological mechanisms behind cryptocurrencies and distributed consensus and distributed ledgers ("blockchains"), introducing along the way the necessary cryptographic tools. It will then focus on more advanced blockchain applications, such as "smart contracts," that is, contracts written as code. Finally, the course will also introduce some of the legal and policy questions surrounding cryptocurrencies. Prerequisites: Introduction to Computer Systems or equivalent strongly recommended

19-351 Applied Methods for Technology-Policy Analysis

Spring: 9 units
This course synthesizes concepts from economics, statistics, decision analysis, and other humanities and social science areas as they relate to analysis of technology and public policy issues. Students will focus on applying skills, tools, and techniques of social science to critically examine issues of current importance to society that have engineering systems at the core, and how public policy can be informed by the results of these analyses. Students will discover the relationship between formulating research questions considering a wide range of perspectives (e.g., political, ethical, social, economic, and legal aspects) and implementing the appropriate research methods for answering them. The course will emphasize interpretation and communication of analysis results in written and oral presentation, especially to non-technical audiences. As a precursor to the EPP Project courses, the course also prepares EPP juniors for structuring real-world problems into a feasible work plan, and to deal with revising work plans as work proceeds.

19-402 Telecommunications Technology and Policy for the Internet Age

Intermittent: 12 units
Modern telecommunications is the nervous system of society. The Internet and wireless communications have transformed every aspect of our modern life. This course provides a comprehensive introduction to basic principles of telecommunications technology and the legal, economic, and regulatory environment of today's networks. Topics covered include the fundamentals of communication network technologies, including video, voice, and data networks; the rising dominance of wireless networks; principles behind telecommunications regulation from common carrier law and natural monopoly to information diversity, privacy and national security; traffic differentiation on the Internet and the debate over network neutrality; universal service and the digital divide; mergers, antitrust, and the changing industrial structure of the communications sector. We will explore current topical questions such as the future of competition; the shift of entertainment video from cable and satellite to Internet delivery; how cloud computing concepts are transforming networks; and communications support for the Internet of Things. Comparison with European approaches to communications regulation. Special emphasis on how new technologies have altered, and are altered by, regulation. Junior, Senior or graduate standing required.
Prerequisites: 73-102 and 73-100

19-403 Policies of Wireless Systems

Intermittent: 12 units
This course will address public policy issues related to wireless systems. It investigates policies related to a wide variety of emerging wireless systems and technologies, including current and next-generation cellular systems, wifi and white space devices, emerging methods of accessing spectrum, communications systems for emergency responders (firefighters, police, emergency medical services), current and next-generation television, and satellite communications. This can include the government role in facilitating the creation of infrastructure, in advancing competition among broadcasters and communications service providers, in using scarce spectrum efficiently, in promoting public safety and homeland security, and in protecting privacy and security. Because these are inherently interdisciplinary issues, the course will include detailed discussions of technology, economics, and law, with no prerequisites in any of these areas. Senior or graduate standing required.

19-411 Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech

Fall: 9 units
Science and Innovation Leadership for the 21st Century introduces students to the fundamental principles surrounding global competitiveness and technological change in the 21st century. The course is broken into three sections. The first section introduces students to competing economic, sociological, and political science theories on the structures supporting technological change. The second section presents the contemporary literature on technological change. The concluding section leverages lessons from the preceding two sections to evaluate national innovation systems, and the factors that lead to national comparative advantage. Students should leave the class able to reflect competently on what the existing literature tells us about the factors influencing global technology competitiveness, and on how modern changes in the structures supporting innovation as well as technology itself may be changing the rules of the game for firms and for nations. The course is open to undergraduate juniors, seniors and amp; graduate students.

19-421 Emerging Energy Policies

Intermittent: 9 units
Interested in what's happening in energy policy and how to analyze potential policy options in response? Focusing on current hot topics in energy policy, students will learn the basic principles of public policy analysis and underlying techniques such as program evaluation, cost benefit analysis, life cycle analysis, prince analysis, and risk analysis as well as the variety of policy mechanisms available. Class time will include a combination of faculty and guest speaker lectures, discussion of issues, videos, and problem solving. Students will review and edit Wikipedia entries on an energy policy topic of their choice, and then analyze policy options resulting in an executive summary or paper on that topic. While the course has no prerequisites, students should feel comfortable with scientific and technical topics. Upon completion of this course, students should have a deeper and more strategic understanding of the opportunities and challenges associated with emerging energy policies. Open to seniors. Open to juniors with permission only.

19-425 Sustainable Energy for the Developing World

Fall and Spring: 9 units
This course examines the current state of the energy system in developing countries and the challenges these countries will face in sustainably meeting their energy needs in the 21st century. The following are examples of questions and issues we will cover throughout the semester. What is the current status of the energy system in the developing world? What is the role of energy in supporting economic growth and alleviating poverty? What are the future energy needs of developing countries? What are the challenges developing countries will face as they build/improve their energy systems? What technologies are available to meet the energy challenges in the developing world?

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5 (https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5/)

19-427 Special Topics: Energy Innovation and Entrepreneurship

Fall: 9 units
Want to be an energy innovator, business entrepreneur, social entrepreneur, or intrapreneur? Students in this class will learn the fundamentals of energy innovation and entrepreneurship, and how innovation and entrepreneurship in energy differs from that in other fields. Students will then develop a business and non-market strategy for an idea of their own, or in response to a real-world challenge proposed by a business, industry, or a non-governmental organization. The resulting strategy can, if students wish, be submitted for student competitions that typically take place each spring throughout the United States.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5 (https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5/)

19-428 Special Topics: Market Engineering and Applications

Intermittent: 9 units
An introduction to market-engineering concepts and applications to contemporary market-design problems such as resource allocation, information aggregation, and decentralized control. Concepts apply theory of linear algebra, optimization and statistics. Course reservations for Seniors; and Juniors with permission. Application areas include: - energy systems, - environmental management (e.g., cap-and-trade systems), - wildlife management (e.g., fishing licenses), - oil-development leases, - exchanges for organ transplants, - information markets, and - matching systems for medical-residency programs.

19-429 Climate Change Science and Solutions

Fall and Spring: 9 units
This course consists of four parts. The first part will provide a primer for those who are curious about the physical mechanisms by which climate is determined, and by which climate change occurs. The treatment of these mechanisms will not be overly quantitative, and no knowledge of meteorology or atmospheric science is needed. College-level physics, as well as basic calculus and basic chemistry, is, however, needed. The second part will describe the projected consequences of climate change, as well as those that are already occurring. This part will also familiarize students with how societies might adapt to these changes. The third part will explore (and critique) some of the tools that decision-makers use to quantify and compare the damages caused by these consequences. The final part of the course will discuss some of the technologies that could be used to prevent dangerous climate change.

19-433 Data Science for Technology, Innovation and Policy

Intermittent: 9 units
Students will learn how to use R to collect, organize, and analyze data in technology, innovation, and policy-related domains. The focus will be on the practical issues faced when conducting data analyses, correctly implementing and interpreting statistical models, and summarizing results for clients and research purposes.

19-440 Combustion and Air Pollution Control

Intermittent: 9 units
Formation and control of gaseous and particulate air pollutants in combustion systems. Basic principles of combustion, including thermochemical equilibrium, flame temperature, chemical kinetics, hydrocarbon chemistry, and flame structure. Formation of gaseous and particulate pollutants in combustion systems. Combustion modifications and postcombustion technologies for pollutant control. Relationship between technology and regional, national, and global air pollution control strategies. The internal combustion engine and coal-fired utility boiler are used as examples.

19-451 EPP Projects I

Fall and Spring: 12 units
Students work in multidisciplinary teams (engineers and scientists, humanities and social scientists, public policy and management graduates) on a cutting edge project topic with very little in the way of pre-digested analysis or solutions. Topics include both technical and social dimensions, multiple constraints on the solutions, and require multi-dimensional analyses. Students are given a general goal, and are expected to discover existing knowledge on the topic, and to research existing technologies and relevant policies. Using this background and their technical and social analysis education as appropriate, students then create new knowledge on the subject and analyzing technology impacts, policy alternatives, or other relevant options as topics necessitate. This knowledge is communicated to an external advisory panel, selected from experts and constituencies of importance to the issue through formal presentations and a written report. #19451 is the first of two EPP Projects course experiences for EPP additional majors, students taking EPP Projects I are learning how to use their skills from prior EPP courses in solving complex, unstructured problems and developing skills for effective project completion.

19-452 EPP Projects II

Fall: 12 units
Students work in multidisciplinary teams (engineers and scientists, humanities and social scientists, public policy and management graduates) on a cutting edge project topic with very little in the way of pre-digested analysis or solutions. Topics include both technical and social dimensions, multiple constraints on the solutions, and require multi-dimensional analyses. Students are given a general goal, and are expected to discover existing knowledge on the topic, and to research existing technologies and relevant policies. Using this background and their technical and social analysis education as appropriate, students then create new knowledge on the subject and analyzing technology impacts, policy alternatives, or other relevant options as topics necessitate. This knowledge is communicated to an external advisory panel, selected from experts and constituencies of importance to the issue through formal presentations and a written report. The second of two EPP Projects course experiences for EPP additional majors, EPP Projects II is the capstone course. Students apply their skills and knowledge from EPP Projects I, demonstrating project framing, decomposition, and developing analyses. Students in this second course are expected to be course leaders, assisting students taking the course for the first time in navigating project communications and tasks.

19-469 Behavior, Decision and Policy

Intermittent: 9 units
Behavioral science can inform policy making in three ways: (a) improving two-way communication between the public and policy makers; (b) creating policies that make realistic assumptions about human behavior; (c) disciplining the expert judgment needed to analyze risks. The course will introduce and discuss the technical and ethical foundations of behavioral research and risk analysis, setting them in their historical, social, and political context. It will apply them to a wide variety of technology-related policies, including energy (e.g., conservation, nuclear power), environment (e.g., climate, pollution), health (e.g., vaccines, COVID-19), national security (e.g., terrorism, intelligence analysis), and others, including ones proposed by students. Students will acquire a critical perspective on policies in their lives, society, and profession. The course is open to juniors, seniors, and graduate students, who have not taken 84369/84669.

19-500 Directed Study in EPP: Undergraduate

All Semesters
Students may do undergraduate research as one course for EPP technical elective credit, with an EPP faculty member, or on an approved project with a faculty member from another department. The research credits must be pre-approved by your advisor, and should result in a written product, one copy of which should be sent to EPP.

19-534 Usable Privacy and Security

Spring: 9 units
There is growing recognition that technology alone will not provide all of the solutions to security and privacy problems. Human factors play an essential role in these areas, and it is important for security and privacy experts to have an understanding of how people will interact with the systems they develop. This course is designed to introduce students to a variety of usability and user-interface problems related to privacy and security and to give them experience in understanding and designing studies aimed at helping to evaluate usability issues in security and privacy systems. The course is suitable both for students interested in privacy and security who would like to learn more about usability, as well as for students interested in usability who would like to learn more about security and privacy. Students will also work on a group project throughout the semester. The course is open to all students who have technical backgrounds. The 12-unit course numbers (17-734, 5-836, 19-734) are for PhD students and masters students. Students enrolled in these course numbers will have extended homework assignments and will be expected to play a leadership role in a group project that produces a paper suitable for publication. The 9-unit course numbers (17-334, 5-436, 19-534) are for undergraduates and masters students (if permitted by their program).

19-550 Undergraduate Research

Intermittent
Students may do undergraduate research as one course for EPP technical elective credit, with an EPP faculty member, or on an approved project with a faculty member from another department. The research credits must be pre-approved by your advisor, and should result in a written product, one copy of which should be sent to EPP.

19-602 Current Topics In Privacy Seminar

Fall and Spring: 3 units
In this seminar course students will discuss recent papers and current public policy issues related to privacy. Privacy professionals from industry, government, and non-profits will deliver several guest lectures each semester.

19-603 Data Science for Technology, Innovation and Policy

Intermittent: 12 units
Students will learn how to use R to collect, organize, and analyze data in technology, innovation, and policy-related domains. The focus will be on the practical issues faced when conducting data analyses, correctly implementing and interpreting statistical models, and summarizing results for clients and research purposes.

19-605 Engineering Privacy in Software

Spring: 12 units
Privacy harms that involve personal data can often be traced back to software design failures, which can be prevented through sound engineering practices. In this course, students will learn how to identify privacy threats due to surveillance activities that enhance modern information systems, including location tracking, behavioral profiling, recommender systems, and social networking. Students will learn to analyze systems to identify the core operating principles and technical means that introduce privacy threats, and they will learn to evaluate and mitigate privacy risks to individuals by investigating system design alternatives. Strategies to mitigating privacy risk will be based on emerging standards and reliable privacy preference data. Students will have the opportunity to study web-, mobile- and cyber-physical systems across a range of domains, including advertising, healthcare, law enforcement and social networking. In addition, students will know how, and when, to interface with relevant stakeholders, including legal, marketing and other developers in order to align software design with privacy policy and law.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5 (https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5/)

19-608 Privacy Policy, Law, and Technology

Fall: 12 units
This course focuses on policy issues related to privacy from the perspectives of governments, organizations, and individuals. We will begin with a historical and philosophical study of privacy and then explore recent public policy issues. We will examine the privacy protections provided by laws and regulations, as well as the way technology can be used to protect privacy. We will emphasize technology-related privacy concerns and mitigation, for example: social networks, smartphones, behavioral advertising (and tools to prevent targeted advertising and tracking), anonymous communication systems, big data, and drones. This is part of a series of courses offered as part of the MSIT-Privacy Engineering masters program. These courses may be taken in any order or simultaneously. Foundations of Privacy (Fall semester) offers more in-depth coverage of technologies and algorithms used to reason about and protect privacy. Engineering Privacy in Software (Spring semester) focuses on the methods and tools needed to design systems for privacy. This course is intended primarily for graduate students and advanced undergraduate students with some technical background. Programming skills are not required. 8-733, 19-608, and 95-818 are 12-unit courses for PhD students. Students enrolled under these course numbers will have extra assignments and will be expected to do a project suitable for publication. 8-533 is a 9-unit course for undergraduate students. Masters students may register for any of the course numbers permitted by their program. This course will include a lot of reading, writing, and class discussion. Students will be able to tailor their assignments to their skills and interests. However, all students will be expected to do some writing and some technical work.

19-617 Infrastructure Management

Intermittent: 12 units
This course takes a broad view of infrastructure systems to include physical infrastructure and information networks. The course will consider the need to protect these critical infrastructures from both degradation as well as malicious attacks. Infrastructure management generally depends on public-private partnerships to ensure long-term viability. We will look at relevant academic literature on the topics of infrastructure needs and requirements. We will explore the use of automated sensing and computer network systems to facilitate management.

19-624 Emerging Energy Policies

Intermittent: 12 units
Interested in what's happening in energy policy and how to analyze potential policy options in response? Focusing on current hot topics in energy policy, students will learn the basic principles of public policy analysis and underlying techniques such as program evaluation, cost benefit analysis, life cycle analysis, prince analysis, and risk analysis as well as the variety of policy mechanisms available. Class time will include a combination of faculty and guest speaker lectures, discussion of issues, videos, and problem solving. Students will review and edit Wikipedia entries on an energy policy topic of their choice, and then analyze policy options resulting in an executive summary or paper on that topic. While the course has no prerequisites, students should feel comfortable with scientific and technical topics. Upon completion of this course, students should have a deeper and more strategic understanding of the opportunities and challenges associated with emerging energy policies. Open to seniors. Open to juniors with permission only.

19-625 Sustainable Energy for the Developing World

Fall and Summer: 12 units
This course examines the current state of the energy system in developing countries and the challenges these countries will face in sustainably meeting their energy needs in the 21st century. The following are examples of questions and issues we will cover throughout the semester. What is the current status of the energy system in the developing world? What is the role of energy in supporting economic growth and alleviating poverty? What are the future energy needs of developing countries? What are the challenges developing countries will face as they build/improve their energy systems? What technologies are available to meet the energy challenges in the developing world?

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5 (https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5/)

19-627 Special Topics: Energy Innovation and Entrepreneurship

Fall: 12 units
Want to be an energy innovator, business entrepreneur, social entrepreneur, or intrapreneur? Students in this class will learn the fundamentals of energy innovation and entrepreneurship, and how innovation and entrepreneurship in energy differs from that in other fields. Students will then develop a business and non-market strategy for an idea of their own, or in response to a real-world challenge proposed by a business, industry, or a non-governmental organization. The resulting strategy can, if students wish, be submitted for student competitions that typically take place each spring throughout the United States.

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19-629 Climate Change Science and Solutions

Fall and Spring: 12 units
This course consists of four parts. The first part will provide a primer for those who are curious about the physical mechanisms by which climate is determined, and by which climate change occurs. The treatment of these mechanisms will not be overly quantitative, and no knowledge of meteorology or atmospheric science is needed. College-level physics, as well as basic calculus and basic chemistry, is, however, needed. The second part will describe the projected consequences of climate change, as well as those that are already occurring. This part will also familiarize students with how societies might adapt to these changes. The third part will explore (and critique) some of the tools that decision-makers use to quantify and compare the damages caused by these consequences. The final part of the course will discuss some of the technologies that could be used to prevent dangerous climate change.

19-639 Policies of the Internet

Fall: 12 units
This course will address public policy issues related to the Internet. This may include policy issues such as network neutrality and the open Internet, Internet governance and the domain name system (and the role of the United Nations), copyright protection of online content, regulation of indecency and pornography, universal access to Internet and Internet as a "human right", government surveillance of the Internet, Internet privacy and security, and taxation of electronic commerce. It will also teach some fundamentals of Internet technology. Because these are inherently interdisciplinary issues, the course will include detailed discussions of technology, economics, and law, with no prerequisites in any of these areas. Senior or graduate standing required.

19-640 Dynamic Network Analysis

Spring: 12 units
Who knows who? Who knows what? Who communicates with whom? Who is influential? How do ideas, diseases, and technologies propagate through groups? How do social media, social, knowledge, and technology networks differ? How do these networks evolve? How do network constrain and enable behavior? How can a network be compromised or made resilient? Such questions can be addressed using Network Science. Network Science, a.k.a. social network analysis and link analysis, is a fast-growing interdisciplinary field aimed at understanding simple and amp; high dimensional networks, from both a static and a dynamic perspective. Across an unlimited application space, graph theoretic, statistical, and amp; simulation methodologies are used. An interdisciplinary perspective on network science is provided, with an emphasis on high-dimensional dynamic data. The fundamentals of network science, methods, theories, metrics and amp; confidence estimation, constraints on data collection and amp; bias, and key research findings and amp; challenges are examined. Illustrative networks discussed include social media based (e.g., twitter), disaster response, organizational, semantic, political elite, crises, terror, and amp; P2P networks. Critical procedures covered include: basic centralities and metrics, group and community detection, link inference, network change detection, comparative analytics, and big data techniques. Applications from business, science, art, medicine, forensics, social media and amp; numerous other areas are explored. Key issues addressed: Conceptualization, measurement, comparison and amp; evaluation of networks. Identification of influential nodes and hidden groups. Network emergence, evolution, change and amp; destabilization. Graduate course taught every other year. Prerequisite: Undergraduate-level statistics course or instructor permission. Linear algebra is recommended. Students are encouraged to bring and amp; use their own data, or to use provided data.

19-654 Regulation of Internet Edge Platforms

Fall: 6 units
Social media, search and e-commerce platforms are under attack all over the world: antitrust lawsuits, complaints about "fake news," partisan bias, and disinformation on social media, calls to remove liability protections for platforms that post user-provided content, to regulate content and online marketplaces. In this course we will examine competing economic and policy approaches to the treatment of these platforms. We will examine where these companies fit in the Internet ecosystem; how these firms make money (e.g. targeted advertising); traditional principles of antitrust and their application to multi-sided platforms; issues of Free Speech versus Disinformation on social networks, and how these firms differ from traditional media; and a comparison of proposals for structural versus behavioral regulation. Readings will be drawn from technical, economic, legal and policy sources. Students will be encouraged to contrast competing approaches to these issues via in-class debates and written assignments.

19-658 Corporate Venturing & Innovation

Intermittent: 6 units
: Startups aren't the only career destination for aspiring and experienced entrepreneurs - large, established companies need entrepreneurs more than ever to help them avoid the risk of being disrupted. The future survival of many large companies is in the hands of entrepreneurs who understand both technology and business - learn the skills you will need to engage corporate executives on the topic of corporate venturing. This course is created to help entrepreneurs design corporate venturing programs for large companies who want to avoid being disrupted by innovative and more nimble startups *How can you convince corporate executives to invest in corporate venturing capabilities? *How can you be successful as an entrepreneur inside a large company that is set on its ways? *How can a large company compete with faster and more nimble startups by building their own?

19-659 Economic Regulation of Networked Industries

Fall: 6 units
Economic Regulation of Networked Industries; This course will examine principles of economic regulation of networked industries such as gas, electricity, water and telecommunications, including economic justifications for price regulation (e.g. natural monopoly); alternative approaches to price regulation (Rate of Return, Price Caps), cost allocation and pricing in multiproduct industries (e.g. Ramsey prices); tariff design (single and multipart tariffs, capacity charges, peak load pricing); regulation in the presence of competition (cross subsidy and predatory pricing; access pricing); and institutional issues in regulatory agencies (design of independent regulatory agencies, incorporation of public input, public choice theory, regulatory capture).
Prerequisite: 73-102

19-664 Special Topics: Advancing Low Carbon Transition in Industry

Intermittent: 12 units
As a widely used and globally traded product, steel is essential to modern life, but its production is highly energy intensive and accounts for roughly 8% of global greenhouse gas emissions. This project course will work with a major U.S. and Pittsburgh-based steel producer to assess technology pathways for the decarbonization of their organization. Students will learn and apply engineering economic approaches as well as perspectives from organizational processes and business strategy to analyze and compare decision alternatives. Skills to be acquired include deep understanding of industrial processes and decarbonization technologies, engineering cost and real options analysis, business strategy and organization, the role of public policy, and project workflow management and presentation skills. The course will involve regular interaction with the executive sponsor and technical lead, as well as experts on steelmaking technology and climate policy, with high potential for impact.

19-666 Energy Policy and Economics

Intermittent: 6 units
This course will begin with a review of microeconomic concepts and tools necessary for analysis of the topics covered in the class. The course will explore how past energy technology policies and choices are intertwined with pathways of economic development, social impacts, macroeconomic measurement and performance. This course will explore how a wide variety of policy mechanisms- technology policy, utility regulation and restructuring, emissions policies, multilateral interventions and agreements, and corporate strategies-can shape energy use and the environmental impacts of energy systems. Study examples will draw from both developed and developing countries.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5 (https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5/)

19-668 Electric Vehicles: Technology, Economics, Environment and Policy

Intermittent: 12 units
In this course, students will read academic literature, government documents, and popular press to develop a broad understanding of the technology, economic, environmental and policy dimensions of electric vehicles. Topics may include (1) TECHNOLOGY: Battery technology, design, application, degradation and innovation; electric vehicle technologies and designs; the electric power grid; (2) ECONOMICS: cost; consumer behavior; infrastructure; electricity dispatch; automotive externalities; the Gruenspecht effect; (3) ENVIRONMENT: life cycle assessment; air pollution; greenhouse gas emissions; marginal grid emission factors; renewables; vehicle to grid; hydrogen; (4) POLICY: effectiveness, efficiency, uncertainty and equity; short-run versus long-run effects; fleet standards; incentives; mandates; policy interactions; intellectual property; and policies in the US, China, EU, Japan, and local jurisdictions. Fundamentals covered at an introductory level to support readings may include time value of money, economies of scale, social welfare analysis, externalities, valuation of reduced mortality risk; choice modeling, regression, life cycle assessment, optimization, game theory, and other topics. Fluency with algebra and calculus is assumed.

19-669 Behavior, Decision and Policy

Intermittent: 12 units
Behavioral science can inform policy making in three ways: (a) improving two-way communication between the public and policy makers; (b) creating policies that make realistic assumptions about human behavior; (c) disciplining the expert judgment needed to analyze risks. The course will introduce and discuss the technical and ethical foundations of behavioral research and risk analysis, setting them in their historical, social, and political context. It will apply them to a wide variety of technology-related policies, including energy (e.g., conservation, nuclear power), environment (e.g., climate, pollution), health (e.g., vaccines, COVID-19), national security (e.g., terrorism, intelligence analysis), and others, including ones proposed by students. Students will acquire a critical perspective on policies in their lives, society, and profession. The course is open to juniors, seniors, and graduate students, who have not taken 84369/84669.

19-670 Quantitative Entrepreneurship: Analysis for New Technology Commercialization

Spring: 12 units
This course provides engineers with a multidisciplinary mathematical foundation for integrated modeling of engineering design, manufacturing, and enterprise planning decisions for commercializing new technologies and products. Topics include economics in product design, manufacturing and operations modeling and accounting, consumer choice modeling, survey design, conjoint analysis, optimization, model integration and interpretation, and professional communication skills. Students will apply theory and methods to a team project for a new product or emerging technology, developing a business plan to defend technical and economic competitiveness. This course assumes fluency with multivariable calculus, linear algebra, and probability theory.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5 (https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5/)

19-671 Tech Start-up: Market Discovery

Spring: 6 units
The first three years of a technology start-up are the most critical; when the company's DNA or trajectory is set. Too few entrepreneurs appreciate this fact and, as a result, many start without the essential skills talents and capabilities needed to set the company on a successful path. Some of these entrepreneurial skills can only be learned through starting and growing a business while others can be learned. This course attempts to bridge the challenging gap between learning and doing entrepreneurship. We introduce you to an essential skill of market discovery or learning to create, develop and evaluate your concept of your business. Is my idea a real innovation? Is it also a business or a product or neither? How do I know how big the market is for my product? What are the technology market and competitive risks in my idea and how do I assess them? Can I compete? Can I sell it? How? When? Where? Students will have the opportunity to apply their newfound practical skills gathered in part from lectures from experienced entrepreneurs and investors to case studies role-playing and solving actual problems of local tech businesses. The best way to learn entrepreneurship is by doing, which is why this course will use 'true-to-life' scenarios as the anchor for the course. The class will be divided into 4 teams will focus on a company that is either (1) a student idea for new start-up, (2) an existing start-up (ideally local) or (3) a hypothetical start-up proposed/conceived by the students, the professor or both

19-672 Special Topics: Tech Start-up: Building Your Own Company

Fall: 6 units
(Session 2) - The first year or two of a tech start-up set the trajectory and character of that company for years to come. Too few entrepreneurs appreciate this reality and, as a result, many carry forward misperceptions and misconceptions about creating and building a successful tech company that set it on the path for failure. This class attempts to remedy that challenge by exposing the student the practical reality of building a team and funding a start-up team. This class should help the student answer (or know how to find the answer) to the following questions: How do I find manage and evaluate a start-up team Do I have the skill motivation and ability to be a tech entrepreneur? Can I build a company from scratch (really?)? Should I be the CEO Sales Account Manager VP of Engineering or something else altogether? How much money do I raise and where and when do I raise it? Students will have the opportunity to apply their newfound practical skills gathered in part from lectures from experienced entrepreneurs and investors to case studies.

19-680 E&TIM Seminar on Innovation Management in Practice

Intermittent: 6 units
A definition of innovation is the combination of technology and commercialization to deliver social and economic value. Corporations utilize innovation to establish a competitive advantage and to differentiate in the marketplace. Public policy makers view innovation as a critical driver for economic development. This course will cover the fundamentals of innovation, and the many challenges associated with it. How are opportunities identified? What are the strategies used, and how can they then be implemented? What roles are played by processes, technologies, and the business environment, as well as by individuals in organizations? This course will include active classroom discussions and readings from the innovation literature to reinforce concepts, develop critical thinking and hone analysis skills.

19-682 The Strategy and Management of Technological Innovation

Intermittent: 12 units
Welcome to the dynamic and transformative realm of "Strategy and Management of Technological Innovation". This course is designed to equip learners with the acumen and practical skills necessary to navigate the rapidly evolving landscape of technology-driven innovation. We will delve deep into the intricacies of conceiving, nurturing, and strategically deploying technological innovations to achieve sustainable competitive advantage. We will emphasize the practical aspects of innovation strategy and management through an extensive array of case studies and real-life examples. Learners will delve into the nuances of go-to-market strategies for new innovations, master the art of sustaining innovation, and explore how disruptive strategies can reshape industries. By the end of this course, learners will be equipped with a robust strategic toolkit, rooted in real-world examples, that will empower them to lead and drive technological innovation within their organization(s), regardless of stage or industry.

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5 (https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5/)

19-684 Engineering and Technology Innovation Management in Practice

Intermittent: 6 units
In this course, we will apply the fundamentals of innovation principles and practices to sponsored projects from corporations. You will work in teams to address the sponsors' objectives, using concepts such as six levers of innovation, seven innovation rules, design roadmapping, etc. Working closely with the sponsor is required so engaging in an appropriate professional manner is expected. Moreover, understanding how to approach team projects, manage team dynamics, and developing presentation skills will also be a part of the curriculum. The course is a culmination of utilizing your learnings from the ETIM program to address customers' needs.

19-685 Engineering Optimization without Project

Intermittent: 9 units
This course introduces students to 1) the process of formally representing an engineering design or decision-making problem as a mathematical problem and 2) the theory and numerical methods needed to understand and solve the mathematical problem. Theoretical topics focus on constrained nonlinear programming, including necessary and sufficient conditions for local and global optimality and numerical methods for solving nonlinear optimization problems. Additional topics such as linear programming, mixed integer programming, global optimization, and stochastic methods are briefly introduced. Model construction and interpretation are explored with metamodeling and model reformulation techniques, study of model boundedness, constraint activity, and sensitivity analysis. Matlab is used in homework assignments for visualization and algorithm development, and students apply theory and methods to a topic of interest in a course project. Fluency with multivariable calculus, linear algebra, and computer programming is expected. Students who are unfamiliar with Matlab are expected to learn independently using available tutorials and examples provided. 4 hrs lecture Prerequisites: None 19785 and 24785: 12-units including the team-based engineering optimization project 19685 and 24685: 9-units excluding the project

19-687 Managing Research, Development and Innovation

Intermittent: 6 units
This course considers key issues and trade-off in R and amp;D strategy and organization, paying attention to dynamic competitive contexts where technology plays a key role. These topics are treated assuming the perspective of the decision maker. It addresses typical problems of large, medium and small firms having a structured R and amp;D and operating businesses where R and amp;D is the source of competitive advantages. Although we will heavily focus on R and amp;D, emphasis is placed on viewing R and amp;D as a part (although, a key part) of the process of technological innovation; therefore, as an activity to be strongly and appropriately integrated with other functions to make innovation successful.

19-688 Tech Start Up: Market Discovery & Building Your Own Company

Intermittent: 12 units
The first year or two of a tech start-up set the trajectory and character of that company for years to come. Too few entrepreneurs appreciate this reality and, as a result, many carry forward misperceptions and misconceptions about creating and building a successful tech company that set it on the path for failure. This class attempts to remedy that challenge by exposing the student the practical reality of building a team and funding a start-up team. This class should help the student answer (or know how to find the answer) to the following questions: How do I find, manage and evaluate a start-up team? Do I have the skill, motivation and ability to be a tech entrepreneur? Can I build a company from scratch (really?)? Should I be the CEO Sales Account Manager VP of Engineering or something else altogether? How much money do I raise and where and when do I raise it? Students will have the opportunity to apply their newfound practical skills gathered in part from lectures from experienced entrepreneurs and investors to case studies. Previously this course was offered as two mini's #19671 and #19672

19-689 Finance for Innovation Management

Intermittent: 6 units
In this course, there will be three main elements all focused around the innovation decision-making process: Basic financial concepts Business case development by innovation project managers. Tools and processes used in innovation decision-making With respect to financial concepts, the course will provide an introduction of the basic financial concepts that corporations use to capture their financial performance including the following: Basic financial statement information income statement / balance sheet / meanings / interpretations / analysis of financial statements/determination of cash flow / annual reports, etc. Performance metrics, ROI, Debt to Equity ratio, EPS, NOPAT, EBITDA, Liquidity, Days outstanding, other appropriate measures The intention of this introduction is to provide future project managers with a sufficient understanding of the financial information that is typically used in building a business case to make innovation decisions both in a corporate setting and in a more entrepreneurial setting. With respect to actual innovation decision-making, the course will examine the various tools and techniques that are used by (1) corporations to make investment decisions in specific R and amp;D projects and (2) entrepreneurial organizations to make investments and gt; decisions in new technical projects. This course will address a number of commonly used decision tools such as: (1) Discounting / Net Present Value calculations (NPV), IRR / Payback Period / ROIC / etc.; (2) Decision and Risk Analysis methodologies; and (3) Portfolio management Finally, the course will develop an understanding of the differences between how corporations and how entrepreneurial firms use these tools, examine the implications of financial analysis techniques on R and amp;D decision-making, and will examine some of the suggested fallacies and the limitations of financial analysis of innovation management.

19-690 M.S. Project

Fall and Spring
For E and amp;TIM and EPP MS students only, with faculty approval.

19-693 Managing and Leading Research and Development

Intermittent: 12 units
This course will provide an insider's look at issues in industrial research and development laboratories that future industrial R and amp;D personnel are likely to face.

Course Website: http://www.ece.cmu.edu/courses/items/18703.html

19-695 Internship Practicum

Summer
Experiential learning opportunities are important educational options for undergraduate and graduate students. One such option is an internship, or practicum. If an internship is an explicit part of an academic program or is supervised by a faculty member, this course number may be used. Please consult the supervising faculty member concerning grading options and the appropriate number of units. NOTE: Special Permission required to register for this course

19-701 Introduction to the Theory and Practice of Policy Analysis

Intermittent: 12 units
This course reviews and critically examines a set of problems, assumptions and analytical techniques that are common to research and policy analysis in technology and public policy. Topics covered include the difference between science, trans-science and policy analysis, policy problems formulated in terms of utility maximization, issues in the valuation of intangibles, uncertainty in policy analysis, selected topics in risk analysis, limitations and alternatives to the paradigm of utility maximization, issues in behavioral decision theory, issues related to organizations and multiple agents, and selected topics in policy advice and policy analysis for the federal government. The objective is to look critically at the strengths, limitations and underlying assumptions of key policy research and analysis tools and problem framing and sensitize students to some of the critical issues of taste, professional responsibility, ethics, and values that are associated with policy analysis and research.

19-702 Quantitative Methods for Policy Analysis

Intermittent: 12 units
Economic framework for identifying and analyzing investment and operation options facing agencies and firms, (both in theory and in practice); economic efficiency, utilization, pricing, and investment; and multi-objective evaluation.

19-703 Applied Data Analysis 1

Intermittent: 6 units
Students will gain a basic understanding of the estimation, interpretation, and diagnostic assessment of the most widely used statistical models in the social sciences. This includes: graphical and inferential statistics, multiple regression with interactions, logistic regression, multi-level models, and panel data. Assignments include six data analysis projects in R. 19703 is part 1, 19704 is part 2.

19-704 Applied Data Analysis 2

Intermittent: 6 units
Students will gain a basic understanding of the estimation, interpretation, and diagnostic assessment of the most widely used statistical models in the social sciences. This includes: graphical and inferential statistics, multiple regression with interactions, logistic regression, multi-level models, and panel data. Assignments include six data analysis projects in R. 19703 is part 1, 19704 is part 2.
Prerequisite: 19-703

19-705 Workshop Applied Policy Analysis

Intermittent: 6 units
This workshop course is about learning how to structure messy un-structured policy problems. It is designed to provide experience in setting up, analyzing, and writing about policy problems of the type that are used in the EPP Part B qualifying exam. Over the course of the semester, the class works through six or seven policy case problems. Much of the work is done in small groups. The principal focus is on integrating the qualitative and quantitative aspects of the problems and on identifying and practicing general problem-solving strategies. Remote option is only with permission of instructor. Students are expected to attend in person.

19-711 Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech

Fall: 12 units
Science and Innovation Leadership for the 21st Century introduces students to the fundamental principles surrounding global competitiveness and technological change in the 21st century. The course is broken into three sections. The first section introduces students to competing economic, sociological, and political science theories on the structures supporting technological change. The second section presents the contemporary literature on technological change. The concluding section leverages lessons from the preceding two sections to evaluate national innovation systems, and the factors that lead to national comparative advantage. Students should leave the class able to reflect competently on what the existing literature tells us about the factors influencing global technology competitiveness, and on how modern changes in the structures supporting innovation as well as technology itself may be changing the rules of the game for firms and for nations. The course is open to undergraduate juniors, seniors and amp; graduate students.

19-713 Policies of Wireless Systems

Intermittent: 12 units
This course will address public policy issues related to wireless systems, and to the Internet. It begins by investigating policies related to a wide variety of emerging wireless systems and technologies, including wifi computer networks, broadband to the home, broadcast radio and television, and satellite communications. This can include the government role in facilitating the creation of infrastructure, in advancing competition among broadcasters and communications service providers, in managing spectrum, and in protecting privacy and security. The course will then address Internet policy issues, which can include Internet governance and the domain name system, taxation, privacy and security, and intellectual property. Because these are inherently interdisciplinary issues, the course will include detailed discussions of technology, economics, and law, with no prerequisites in any of these areas. Note: ECE students must take this course under #18-650 only

19-714 Environmental Life Cycle Assessment

Spring: 12 units
Cradle-to-grave analysis of new products, processes and policies is important to avoid undue environmental harm and achieve extended product responsibility. This course provides an overview of approaches and methods for life cycle assessment and for green design of typical products and processes using the ISO 14040 family of standards. This includes goal and scoping definition, inventory analysis, life cycle impact assessment (LCIA), interpretation, and guidance for decision support. Process-based analysis models, input-output and hybrid approaches are presented for life cycle assessment. Example software such as MATLAB, Excel, and Simapro are introduced and used in assignments. A group life cycle assessment project consistent with the principles and tools of sustainability to solve real-world engineering problems is required.
Prerequisites: (12-706 or 12-421) and 12-712

Course Website: https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5 (https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5/)

19-717 Sustainable Engineering Principles

Fall: 12 units
This course presents an overview of the concept of sustainability, including changing attitudes and values toward technology and the environment through the late twentieth and early twenty-first centuries. Relevant issues in sustainable engineering, including population growth, urbanization, energy, water, food and material resources are discussed. Tools for sustainable engineering are presented, including metrics of sustainability, principles of design for the environment, and use of material and energy balances in sustainable systems. Publicly available data sets and computational models will be explored to assess sustainability. A team-based project is required.

19-726 Mathematical Modeling of Environmental Quality Systems

Spring: 12 units
Development and application of mathematical models for environmental systems. Material balance formulations and their solutions, computer implementation, model validation, uncertainty analysis, and use for projection and policy analysis. Applications to surface water, groundwater, atmospheric transport, indoor air pollution, and human exposure and risk.

19-728 Special Topics: Market Engineering and Applications

Intermittent: 12 units
An introduction to market-engineering concepts and applications to contemporary market-design problems such as resource allocation, information aggregation, and decentralized control. Concepts apply theory of linear algebra, optimization and statistics. Application areas include: - energy systems, - environmental management (e.g., cap-and-trade systems), - wildlife management (e.g., fishing licenses), - oil-development leases, - exchanges for organ transplants, - information markets, and - matching systems for medical-residency programs. All students are automatically placed on the wait list, EPP and ESTP students will be given first priority to enroll in the course. You will be notified once you are enrolled.

19-751 Air Quality Engineering

Intermittent: 12 units
The course provides a quantitative introduction to the processes that control atmospheric pollutants and the use of mass balance models to predict pollutant concentrations. We survey major processes including emission rates, atmospheric dispersion, chemistry, and deposition. The course includes discussion of basic atmospheric science and meteorology to support understanding air pollution behavior. Concepts in this area include vertical structure of the atmosphere, atmospheric general circulation, atmospheric stability, and boundary layer turbulence. The course also discusses briefly the negative impacts of air pollution on society and the regulatory framework for controlling pollution in the United States. The principles taught are applicable to a wide variety of air pollutants but special focus is given to tropospheric ozone and particulate matter. The course is intended for graduate students as well as advanced undergraduates. It assumes a knowledge of mass balances, fluid mechanics, chemistry, and statistics typical of an undergraduate engineer but is open to students from other scientific disciplines.

19-785 Engineering Optimization

Fall: 12 units
This course introduces students to 1) the process of formally representing an engineering design or decision-making problem as a mathematical problem and 2) the theory and numerical methods needed to understand and solve the mathematical problem. Theoretical topics focus on constrained nonlinear programming, including necessary and sufficient conditions for local and global optimality and numerical methods for solving nonlinear optimization problems. Additional topics such as linear programming, mixed integer programming, global optimization, and stochastic methods are briefly introduced. Model construction and interpretation are explored with metamodeling and model reformulation techniques, study of model boundedness, constraint activity, and sensitivity analysis. Matlab is used in homework assignments for visualization and algorithm development, and students apply theory and methods to a topic of interest in a course project. Fluency with multivariable calculus, linear algebra, and computer programming is expected. Students who are unfamiliar with Matlab are expected to learn independently using available tutorials and examples provided. 4 hrs lecture Prerequisites: None 19785 and 24785: 12-units including the team-based engineering optimization project 19685 and 24685: 9-units excluding the project

19-819 A/B Testing, Design, and Analysis

Spring: 6 units
This course looks at how to use A/B testing to measure causal effects in online platforms in the era of big data analytics. We aim at answering questions such as how does the demand for a product change when the price does or the ratings do? How can we anticipate how sales and profits change if the firm changes its business strategy? Facebook, Google, Amazon and similar firms ask and answer questions of this kind everyday using their large online platforms. This course introduces fundamental concepts to correctly ask this type of question. We study frameworks to measure causal effects and we discuss their pros and cons. Every tool is discussed in the context of a specific example that students work on using real world datasets. Significant effort is placed on understanding how to design randomized experiments (aka A/B tests) to measure causal effects. We also discuss the most common challenges that arise when trying to design such experiments in the wild and in network settings. The concepts and tools discussed in this course are general in nature and can be applied in settings other than online platforms such as energy, transportation and education. The examples in class will be mostly drawn from our own work at the Heinz College on the media industry. Lectures are 3 hours long. In the first half of each lecture we go over concepts behind A/B tests and what to do when A/B tests are unavailable. The discussion is based on the ideas and intuition behind these concepts. In the second half of each lecture we go over specific examples and #8212; we study the associated datasets and the code used to analyze them properly. Student evaluation is based on five weekly homeworks and a brief term project to be developed in teams. Instructor: Pedro Ferreira, www.andrew.cmu.edu/user/pedrof Pre-requisites: Knowledge of R or STATA. A class in statistics and regression analysis or permission of the instructor.

19-867 Decision Analytics for Business and Policy

Intermittent: 12 units
This course introduces modeling frameworks and computational tools to address complex, ill-defined, large-scale decision-making problems that arise in policy and business. Using a combination of lecturing, case studies and class discussions, it covers advanced methods of decision-making under uncertainty in four major areas: large-scale optimization, discrete event simulation, stochastic optimization and queuing theory. The application of such methods are drawn from a variety of real-world settings in a variety of domains such as transportation, energy, information systems, health care, supply chain management, etc. Participants are expected to take active learning roles in the computational application of the materials presented in class using the R programming language and the CPLEX optimization solver. A term project simulates realistic and challenging professional situations where new solutions need to be developed, implemented and communicated. The prerequisite is an introductory course in Operations Research, such as Management Science I and II or Decision-Making under Uncertainty. The learning objectives of this course fall into the following categories learning advanced quantitative modeling and solution algorithms from the fields of Operations Research and Management Science (OR/MS) applying OR/MS methods systematically to model complex decision-making problems faced in practice implementing simulation and optimization methods with large-scale datasets using state-of-the-art software evaluating the challenges and trade-offs in quantitative modeling and computation communicating technical models and results effectively based on the context and the audience
Prerequisites: 90-760 and 90-722 and 90-819

Department of Materials Science and Engineering

Elizabeth Dickey, Head
Location: Wean Hall 3327
materials.cmu.edu (http://materials.cmu.edu)

Materials Science & Engineering (MSE) is an engineering discipline that applies the tools of basic and applied sciences and engineering to the manufacture and application of materials and devices. The four broad classes of Materials to which this paradigm is applied are metals, polymers, ceramics, and composites. Essentially every technology (historical, modern, and future) depends on materials development and innovation.

The overarching paradigm of MSE is to determine and to exploit the connection between processing, structure, and properties of materials to engineer materials that fit the performance criteria for specific applications, which are useful for the technological needs of our society. In addition to this product specific knowledge, MSE is concerned with the implications of materials production and their sustainable use on the environment and energy resources.

Graduates of the MSE department are pursuing careers in an expanding spectrum of companies, national laboratories, and universities. Their activities cover a wide range of materials related endeavors that include microelectronics, energy production and storage, biomedical applications, aerospace, information technology, nanotechnology, manufacturing and materials production. Many of our undergraduate alumni choose to attend graduate school; they are accepted into the top Materials graduate schools in the country.

The standard curriculum of the department provides fundamental training for all materials science and engineering areas (see www.cmu.edu/engineering/materials/undergraduate_program/curriculum (http://www.cmu.edu/engineering/materials/undergraduate_program/curriculum/)). The core courses provide understanding and training on tools for working with the (atomic) structure of materials that governs their properties, the thermodynamic relationships that govern the stability of materials, and the rates at which changes take place in materials. Students complete their learning with a capstone design experience in the final year, which integrates their materials knowledge and training with engineering team skill development. To supplement the core course program, students may also participate in the current research programs of the faculty and conduct undergraduate research projects as part of their program of study.

While the core program is focused on the understanding of the internal or surface structure of materials in order to predict and engineer their properties, it is a flexible program that allows students to focus within a chosen material class, whether it is ceramics, semiconductors, metals, composites, magnetic or optical materials, bio-materials or polymers. The program also permits the option of cross concentration in the one or more of the areas of application such as electronic materials*, engineering design*, environmental engineering*, additive manufacturing*, mechanical behavior of materials*, biomedical engineering**, and engineering and public policy**, is also available. (*= Designated Minor, **= Additional Major). Our curriculum is designed to provide a strong foundation in fundamental knowledge and skills that provide an excellent base for our graduates planning to continue on to graduate studies. For our graduates who seek employment in industry, the program provides the foundation on which a graduate can build his/her domain specific knowledge. For students that develop or seek opportunities in other disciplines after graduation, the MSE curriculum provides a modern liberal education combined with the engineering rigors, i.e. one that inculcates upon a thoughtful, problem-solving approach to professional life. It is thus the goal of our education to provide a global and modern education in Materials Science and Engineering to support our graduates during their careers in materials industries or as a foundation for further studies in any of the leading global institutions of graduate education.

Accreditation

The Materials Science and Engineering Program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the commission's General Criteria and the Program Criteria for Materials(1), Metallurgical(2), Ceramics(3) and Similarly Named Engineering Programs.

Program Educational Objectives

Graduates with a B.S. degree from the Materials Science and Engineering program will, within a few years after graduation

(1) attain success in a professional position and/or a top graduate school that builds upon their MSE background

(2) exhibit professionalism and leadership in contemporary, interdisciplinary engineering practice based on materials, while accounting for the impact of their profession on an evolving, global society

(3) contribute to innovative designs of technological systems using principles of materials science and engineering

(4) make effective contributions as an individual, team member, and/or a leader to effect global, economic, environmental, and/or societal impact

Student Outcomes

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

3. an ability to communicate effectively with a range of audiences

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Curriculum

Minimum units requrired for B.S. in Materials Science & Engineering	381

Standard Program

Freshman Year

Fall		Units
21-120	Differential and Integral Calculus	10
27-100	Engineering the Materials of the Future *	12
99-101	Core@CMU	3
xx-xxx	General Education Course	9
33-141	Physics I for Engineering Students	12
		46

Spring		Units
21-122	Integration and Approximation	10
xx-xxx	Second Introductory Engineering Course	12
33-142	Physics II for Engineering and Physics Students	12
76-101	Interpretation and Argument	9
		43

Sophomore Year

Fall		Units
27-201	Structure of Materials	9
27-210	Materials Engineering Essentials	6
27-215	Thermodynamics of Materials	12
09-105	Introduction to Modern Chemistry I **	10
21-254	Linear Algebra and Vector Calculus for Engineers	11
15-110	Principles of Computing	10
or 15-112	Fundamentals of Programming and Computer Science	
39-210	Experiential Learning I	0
		58

Spring		Units
27-202	Defects in Materials	9
27-216	Transport in Materials	9
27-217	Phase Relations and Diagrams	12
21-260	Differential Equations	9
39-220	Experiential Learning II	0
xx-xxx	General Education Course	9
		48

Junior Year

Fall		Units
27-301	Microstructure and Properties I	9
27-xxx	MSE Restricted Elective [1]	9
xx-xxx	Free Elective [1]	9
33-225	Quantum Physics and Structure of Matter or	9
or 09-217	Organic Chemistry I	
or 03-121	Modern Biology	
xx-xxx	General Education Course	9
39-310	Experiential Learning III	0
		45

Spring		Units
27-367	Selection and Performance of Materials	6
27-305	Introduction to Materials Characterization	6
xx-xxx	General Education Course	9
27-xxx	MSE Restricted Elective [2]	9
27-xxx	MSE Restricted Elective [3]	9
xx-xxx	Free Elective [2]	9
36-220	Engineering Statistics and Quality Control	9
		57

Senior Year

Fall		Units
27-401	MSE Capstone Course I	6
27-xxx	MSE Restricted Elective [4]	9
xx-xxx	Free Elective [3]	9
xx-xxx	General Education Course	9
xx-xxx	General Education Course	9
		42

Spring		Units
27-402	MSE Capstone Course II	6
27-xxx	MSE Approved Technical Elective	9
xx-xxx	Free Elective [4]	9
xx-xxx	Free Elective [5]	9
xx-xxx	General Education Course	9
		42

* The Materials in Engineering course 27-100 may also be taken in the spring semester, and must be taken before the end of the sophomore year (the H&SS Elective in the Sophomore Spring may be moved to later in the program to accommodate the 27-100 course).

** These courses must be taken before the end of the sophomore year, but need not be taken in the same order or semester as listed above.

All mathematics (21-xxx) courses required for the engineering degree taken at Carnegie Mellon must have a minimum grade of C in order to be counted toward the graduation requirement for the BS engineering degree.

Notes on the Curriculum

Academic Advising

Paige Houser is the academic advisor for all MSE students.

Quality Point Average

In addition to the College requirement of a minimum cumulative quality point average of 2.00 for all courses taken beyond the freshman year, the Department requires a quality point average of 2.00 or higher in courses taken in the MSE department. Students may repeat a course to achieve the QPA requirement. Only the higher grade will be used for this departmental calculation.

MSE Approved Technical Elective

Students are required to take at least 9 units of approved technical electives. Students may take a course from another CIT department to fulfill this requirement or choose an additional 9 units of MSE Restricted Electives. Courses on the exclusion list **cannot** be counted as a technical elective. Students who are pursuing an additional major or minor within CIT should check with their academic advisor regarding double counting of this course.

Courses on this list cannot be counted as a technical elective		Units
06-426	Experimental Colloid Surface Science	9
06-466	Experimental Polymer Science	9
12-201	Geology	9
18-202	Mathematical Foundations of Electrical Engineering	12
18-300	Fundamentals of Electromagnetics	12
24-311	Numerical Methods	12
42-202	Physiology	9
42-610	Introduction to Biomaterials	9

MSE Restricted Electives

Each student in the program must take at least 36 units of MSE restricted electives. Up to 18 units of MSE research can count toward the restricted electives.

All 27-3xx, 27-4xx, 27-5xx, 27-6xx (with the exception of) and 27-7xx level and cross listed courses will fulfill the MSE Restricted Elective Requirement along with the following non-MSE courses:

Non-MSE courses that count as restricted electives		Units
06-609	Physical Chemistry of Macromolecules	9
09-509	Physical Chemistry of Macromolecules	9
12-411	Project Management for Engineering and Construction	9
12-631	Structural Design	12
18-310	Fundamentals of Semiconductor Devices	12
24-262	Mechanics II: 3D Design	10
24-341	Manufacturing Sciences	9
42-667	Biofabrication and Bioprinting	12

Integrated B.S./M.S. Program

Undergraduates who excel academically have the unique opportunity to receive simultaneously or sequentially both B.S. and M.S. degrees from the department. The primary purpose of the Integrated Master and Bachelor (IMB) Degree Program is to provide students with superior breadth and depth in technical material, which will better prepare them for careers in industry. Students interested in pursuing the IMB Degrees are encouraged to begin taking some of the required graduate courses before their last year. The MSE department offers two M.S. degrees: one in Materials Science and Engineering (MSE), a coursework degree, and one in Materials Science (MS), a coursework + research degree. The IMB Degree Program to obtain an M.S. in MSE (MS) degree normally requires two (three to four) additional full academic semesters of coursework (coursework + research) beyond the B.S. Degree Requirements (normally eight academic semesters). Experience has shown that students complete the IMB program in eight to ten full academic semesters after enrolling at CMU.

Degree Requirements

IMB students can be enrolled in either the M.S. in MSE (coursework) or the M.S. in MS (coursework + research) degree programs, depending on their preference.
Students must meet the requirements of either the M.S. in MSE or the M.S. in MS degree programs, as well as any specially stated rules below.

Eligibility

The IMB Program is available to all undergraduates who maintain a cumulative QPA of 3.0 or better, including the freshman year and the years in which they are enrolled in the IMB. Exceptions can be made by the Department on the basis of other factors, including extenuating (e.g., medical) circumstances, improvement in grades, strong recommendation letters, etc.
Students become eligible to apply to the program during the spring semester of their junior year (5th semester), or the semester in which they accumulate 280 or more units, whichever is earlier.

Enrollment

Students interested in the IMB program are not required to follow the formal application process for acceptance into the MSE graduate program. There is no requirement to provide a formal application, application fee, GRE scores, recommendation letters, official transcripts, or a statement of purpose. Interested students are encouraged request acceptance into the program by contacting the MSE academic advisor by email prior to the middle of the semester in which they become eligible.

Requirements to Enroll as a Graduate Student

If a student takes more than 8 semesters to complete both the B.S. and M.S. in MSE (coursework), then he or she must be a graduate student for at least one full-time 14-week academic semester (Fall or Spring) before graduating, whether or not they have already completed their B.S. degree.

Students should refer to the College of Engineering and University policies regarding enrollment status.

Tuition Assistance

When a student is a full-time graduate student through the IMB program, the department is able to provide some tuition assistance through optional Teaching Assistantships.

Faculty

CHRISTOPHER BETTINGER, Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2010–

MICHAEL BOCKSTALLER, Professor – Ph.D., Max-Planck Institute for Polymer Research; Carnegie Mellon, 2005–

ITZHAQ COHEN-KARNI, Professor – Ph.D., Harvard University; Carnegie Mellon, 2013–

ELIZABETH C. DICKEY, Professor and Department Head – Ph.D., Northwestern University; Carnegie Mellon, 2021–

MARC DE GRAEF, Professor – Ph.D., Catholic University Leuven (Belgium); Carnegie Mellon, 1993–

ADAM FEINBERG, Professor – Ph.D., University of Florida; Carnegie Mellon, 2010–

ROBERT HEARD, Teaching Professor – Ph.D., University of Toronto; Carnegie Mellon, 2003–

MOHAMMAD F. ISLAM, Professor of Materials Science and Engineering – Ph.D., Lehigh University; Carnegie Mellon, 2005–

AMANDA R. KRAUSE, Assistant Professor – Ph.D., Brown University; Carnegie Mellon, 2022–

RACHEL KURCHIN, Assistant Research Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2022–

NOA MAROM, Associate Professor – Ph.D., Weizmann Institute of Science; Carnegie Mellon, 2016–

MICHAEL E. MCHENRY, Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1989–

THOMAS O'CONNOR, Assistant Professor – Ph.D., Johns Hopkins University; Carnegie Mellon, 2021–

P. CHRIS PISTORIUS, Professor and Associate Department Head – Ph.D., University of Cambridge; Carnegie Mellon, 2008–

LISA M. PORTER, Professor – Ph.D., North Carolina State; Carnegie Mellon, 1997–

GREGORY S. ROHRER, Professor – Ph.D., University of Pennsylvania; Carnegie Mellon, 1990–

ANTHONY D. ROLLETT, Professor – Ph.D., Drexel University; Carnegie Mellon, 1995–

PAUL A. SALVADOR, Professor and Executive Director of the Masters program in Energy Science, Technology and Policy – Ph.D., Northwestern University; Carnegie Mellon, 1999–

MAREK SKOWRONSKI, Professor – Ph.D., Warsaw University; Carnegie Mellon, 1988–

VINCENT SOKALSKI, Teaching Professor – Ph.D., Carnegie Mellon; Carnegie Mellon, 2013–

S. MOHADESEH TAHERI-MOUSAVI, Assistant Professor – Ph.D., Ecole Polytechnique Federale de Lausanne; Carnegie Mellon, 2022–

ELIAS TOWE, Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2001–

BRYAN A. WEBLER, Professor – Ph.D., Carnegie Mellon; Carnegie Mellon, 2013–

JAY WHITACRE, Professor – Ph.D., University of Michigan; Carnegie Mellon, 2007–

Affiliated Faculty

ROSALYN ABBOT, Assistant Professor of Biomedical Engineering – Ph.D., Universtiy of Vermont;

AMIT ACHARYA, Professor, Civil and Environmental Engineering – Ph.D., University of Illinois, Urbana-Champaign; Carnegie Mellon, 2000–

JAMES BAIN, Professor, Electrical and Computer Engineering – Ph.D., Stanford University; Carnegie Mellon, 1993–

JACK BEUTH, Professor, Mechanical Engineering – Ph.D., Harvard University; Carnegie Mellon, 1992–

PHIL CAMPBELL, Research Professor, Institute for Complex Engineered Systems – Ph.D., The Pennsylvania State University; Carnegie Mellon, 2000–

KAUSHIK DAYAL, Professor of Civil and Environmental Engineering – Ph.D., California Institute of Technology; Carnegie Mellon, 2008–

MAARTEN DE BOER, Professor of Mechanical Engineering – Ph.D., University of Minnesota; Carnegie Mellon, 2007–

AMIR BARATI FARIMANI, Assistant Professor – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2018–

RANDALL FEENSTRA, Professor, Physics – Ph.D., California Institute of Technology Carnegie Mellon; Carnegie Mellon, 1995–

ERICA FUCHS, Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2007–

STEPHEN GAROFF, Professor Emeritus, Physics – Ph.D., Harvard University; Carnegie Mellon, 1988–

REEJA JAYAN, Associate Professor, Mechanical Engineering – Ph.D., University of Texas at Austin; Carnegie Mellon, 2015–

DAVID KINDERLEHRER, Professor, Mathematical Sciences – Ph.D., University of California, Berkeley; Carnegie Mellon, 1990–

JOHN KITCHIN, Professor of Chemical Engineeering – Ph.D., University of Delaware; Carnegie Mellon, 2006–

TOMEK KOWALWESKI, Professor of Chemistry – Ph.D., Polish Academy of Sciences; Carnegie Mellon, 2000–

SHAWN LITSTER, Professor, Mechanical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2008–

SARA MAJETICH, Professor, Physics – Ph.D., University of Georgia; Carnegie Mellon, 1990–

CARMEL MAJIDI, Professor of Mechanical Engineering – Ph.D., University of California; Carnegie Mellon, 2011–

JONATHAN MALEN, Professor – Ph.D., University of California, Berkeley; Carnegie Mellon, 2009–

KRZYSZTOF MATYJASZEWSKI, J.C. Warner Professor of Natural Sciences, Department of Chemistry and Materials Science and Engineering – Ph.D., Polytechnical University of Łódź, Poland; Carnegie Mellon, 1985–

ALAN MCGAUGHEY, Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2005–

SNEHA PRABHA NARRA, Assistant Professor, Mechanical Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2021–

O. BURAK OZDOGANLAR, Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2004–

RAHUL PANAT, Associate Professor of Mechanical Engineering – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2017–

ROBERT SEKERKA, University Professor Emeritus, Physics, Mathematics and Materials Science – Ph.D., Harvard; Carnegie Mellon, 1969–

SHENG SHEN, Professor, Mechanical Engineering – Ph.D. , Massachusetts Institute of Technology; Carnegie Mellon, 2011–

ROBERT SUTER, Professor Emeritus – Ph.D. , Clark University; Carnegie Mellon University; Carnegie Mellon, 1978, 1981–

FATMA ZEYNEP TEMEL, Assistant Professor, Robotics Institute – Ph.D., Sabanci University; Carnegie Mellon, 2019–

ZACHARY ULISSI, Associate Professor, Chemical Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon University; Carnegie Mellon, 2016–

NEWELL R. WASHBURN, Associate Professor of Chemistry, Biomedical Engineering and Materials Science and Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 2004–

MICHAEL WIDOM, Professor of Physics – Ph.D., University of Chicago; Carnegie Mellon, 1985–

LINING YAO, Assistant Professor of Human-Computer Interaction Institute and College of Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2017–

JIAN-GANG ZHU, Professor, Electrical and Computer Engineering – Ph.D., University of California at San Diego,; Carnegie Mellon, 1997–

Emeriti Faculty

ROBERT F. DAVIS, Professor Emeritus – Ph.D., University of California, Berkeley; Carnegie Mellon, 2004–

WARREN M. GARRISON, Professor Emeritus of Materials Science and Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 1984–

ANDREW GELLMAN, Professor Emeritus, Chemical Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 1992–

DAVID E. LAUGHLIN, Professor Emeritus – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1974–

PAUL WYNBLATT, Professor Emeritus of Materials Science and Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 1981–

Adjunct Faculty

AHARON INSPEKTOR, Adjunct Faculty, Materials Science and Engineering – Ph.D., Technion Israel Institute of Technology; Carnegie Mellon, 2019–

Department of Materials Science and Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

27-052 Introduction to NanoScience and Technology

Summer: 9 units
This course is offered within Carnegie Mellon's Advanced Placement Early Admissions (APEA) program. The course is primarily intended to provide an introduction to nanoscience and technology to a wide audience of students at the advanced high school to incoming freshmen level. The course goals are twofold: (1) to provide students with a holistic view of the objectives, opportunities and challenges of the emerging field of nanotechnology and 2) to sensitize students at an early stage of their career to the relevance of the connections among the traditional disciplines as a vital element to the progress in interdisciplinary areas such as nanotechnology. The course will cover: Introduction and fundamental science; Preparation of nanostructures; Characterization of nanostructures; Application examples, Social and ethical aspects of nanotechnology. Admission according to APEA guidelines.

27-100 Engineering the Materials of the Future

Fall and Spring: 12 units
Materials form the foundation for all engineering applications. Advances in materials and their processing are driving all technologies, including the broad areas of nano-, bio-, energy, and electronic (information) technology. Performance requirements for future applications require that engineers continue to design both new structures and new processing methods in order to engineer materials having improved properties. Applications such as optical communication, tissue and bone replacement, fuel cells, and information storage, to name a few, exemplify areas where new materials are required to realize many of the envisioned future technologies. This course provides an introduction to how science and engineering can be exploited to design materials for many applications. The principles behind the design and exploitation of metals, ceramics, polymers, and composites are presented using examples from everyday life, as well as from existing, new, and future technologies. A series of laboratory experiments are used as a hands-on approach to illustrating modern practices used in the processing and characterization of materials and for understanding and improving materials' properties.

27-201 Structure of Materials

Fall: 9 units
This course covers the fundamentals of crystallography and diffraction. Topics covered include: the periodic table of the elements, bonding in different classes of materials, Bravais lattices, unit cells, directions and planes, crystal geometry computations, direct and reciprocal space, symmetry operations, point and space groups, nature of x-rays, scattering in periodic solids, Bragg's law, the structure factor, and the interpretation of experimental diffraction patterns. 24 crystal structure types of importance to various branches of materials science and engineering will be introduced. Amorphous materials, composites and polymers are also introduced. This course includes both lectures and laboratory exercises.
Prerequisite: 21-122 Min. grade C

27-202 Defects in Materials

Fall: 9 units
Defects have a fundamental influence on the properties of materials, including deformation, electrical, magnetic, optical, and chemical properties, as well as the rates of diffusion in solids. As such, by the controlling the population of intrinsic and extrinsic defects, one can tailor the properties of materials towards specific engineering applications. The objective of this course, which includes classroom and laboratory sessions, is to define approaches to quantifying the populations and properties of defects in crystals. The course will be divided into three sections: point defects, dislocations, and planar defects. The formation of point defects and their influence on diffusion, electrical, and magnetic properties will be considered. The properties and characteristics of dislocations and dislocation reactions will be presented, with a focus on the role of dislocations in deformation. The crystallography and energetics of planar defects and interfaces will also be described, with a focus on microstructural evolution at high temperatures. Time permitting, volume defects or other special topics are also discussed.
Prerequisites: (27-215 or 27-201) and (21-120 Min. grade C or 21-122 Min. grade C)

27-210 Materials Engineering Essentials

Fall: 6 units
This course approaches professional skill holistically, having materials science and engineering students understand that being a professional includes having competencies and responsibilities that are personal, organizational and professional.
Prerequisites: 21-120 Min. grade C or 21-122 Min. grade C

27-211 Structure of Materials (Minor Option)

Fall: 6 units
This course is identical to 27-201, but without the 3-unit lab component.

27-212 Defects in Materials (Minor Option)

Spring: 6 units
THIS IS FOR THE MSE MINOR ONLY: Defects have a fundamental influence on the properties of materials, including deformation, electrical, magnetic, optical, and chemical properties, as well as the rates of diffusion in solids. As such, by the controlling the population of intrinsic and extrinsic defects, one can tailor the properties of materials towards specific engineering applications. The objective of this courseis to define approaches to quantifying the populations and properties of defects in crystals. The course will be divided into three sections: point defects, dislocations, and planar defects. The formation of point defects and their influence on diffusion, electrical, and magnetic properties will be considered. The properties and characteristics of dislocations and dislocation reactions will be presented, with a focus on the role of dislocations in deformation. The crystallography and energetics of planar defects and interfaces will also be described, with a focus on microstructural evolution at high temperatures. Time permitting, volume defects or other special topics are also discussed.

27-215 Thermodynamics of Materials

Fall: 12 units
The first half of the course will focus on the laws of thermodynamics and the inter-relations between heat, work and energy. The concept of an equilibrium state of a system will be introduced and conditions which must be satisfied for a system to be at equilibrium will be established and discussed and the concepts of activity and chemical potential introduced. The second half of the course will focus on chemical reactions, liquid and solid solutions, and relationships between the thermodynamics of solutions and binary phase diagrams.

27-216 Transport in Materials

Spring: 9 units
This course is designed to allow the student to become familiar with the fundamental principles of heat flow, fluid flow, mass transport and reaction kinetics. In addition, the student will develop the skills and methodologies necessary to apply these principles to problems related to materials manufacture and processing. Topics will include thermal conductivity, convection, heat transfer equations, an introduction to fluid phenomena viscosity, etc., Newtons and Stokes Laws, mass momentum balances in fluids, boundary layer theory, diffusion and absolute reaction rate theory. Where appropriate, examples will be taken from problems related to the design of components and the processing of materials.
Prerequisites: 27-210 and 27-215

27-217 Phase Relations and Diagrams

Spring: 12 units
Stability of structures. Hume-Rothery rules. Free energy-composition curves with applications to binary and ternary phase diagrams. Quantitative concepts of nucleation and growth with examples from solidification. Development of microstructures in various classes of phase diagram under near-equilibrium conditions. Atomic mechanisms of solid state diffusion and approach to equilibrium through diffusion.
Prerequisites: 27-215 and 27-201

27-227 Phase Relations and Diagrams (Minor Option)

Spring: 9 units
This course is identical to 27-217, but without the 3-unit lab component.

27-301 Microstructure and Properties I

Fall: 9 units
The objective of this course is to convey some of the essential concepts in materials science and engineering that relate properties (strength, toughness, formability, elasticity, magnetism, thermal expansion, for example) to the microstructure (crystal structure, dislocation structure, grain size, atoms in solids solution, precipitate characteristic, cellular materials). These relationships will be illustrated in terms of idealized materials and actual materials used in many applications. The course contains both lectures and laboratory exercises. The labs will include studies of recrystallization, the effect of microstructure on the properties of wood and the effect of microstructure on the mechanical behavior of a low ally steel, 4140.
Prerequisites: 27-217 and 27-216

27-305 Introduction to Materials Characterization

Spring: 6 units
The course introduces the modern methods of materials characterization, including characterization of microstructure and microchemistry of materials. A classroom component of the course will introduce the wide array of methods and applications of characterization techniques. Basic theory will be introduced where needed. Students will then be instructed in the use of several instruments such as AFM, SEM, and EDS, using a hands-on approach. All instruments are part of the existing lab facilities within MSE and CIT. The methods learned in this course will serve the student during several other higher level courses, such as the Senior level MSE Capstone Course (27-401).
Prerequisite: 27-301

27-306 Special Topics: Processing Of Materials

Fall: 9 units
Processing of a material greatly influences its structure (i.e., crystal structure, phases, and microstructure) and therefore its properties and performance. The objective of this course is to introduce the fundamentals of materials processing that apply to metals, ceramics, and polymers. With a unified approach, various processing routes from melt and powder processing to additive manufacturing will be discussed. Finally, this course will include hands-on, in-class fabrication of diverse shaped objects using 3D printers and filaments of polymers and polymer composites of fibers and ceramic particles that will allow exploration and application of material processing knowledge.

27-357 Introduction to Materials Selection

Spring: 6 units
In this course we follow the design-led approach to evaluate possible materials. In this approach, we start with a property (or combination of properties) which are relevant to a particular design, and then consider what classes of materials and what specific materials meet the design criteria. The logical path is hence from application to material. We shall give attention to materials fundamentals (such as grains and bonding) where these are relevant and useful to understanding differences between different materials - such as why the elastic modulus of steel cannot be changed by heat treatment or alloying, whereas the strength can be changed a great deal.

27-367 Selection and Performance of Materials

Spring: 6 units
This course teaches the selection methodologies for materials and processes for satisfaction of a design goal. Topics such as performance under load, shape effects, material properties (intrinsic and as influenced by processing) are discussed and applied so as to determine the fitness of use of materials for applications. Expanded topics include economics, codes and standards, environmental and safety regulations, professional ethics and life cycle analysis where applicable. The course incorporates a project where virtual teams work to provide material selection for a specific application problem.
Prerequisites: 27-301 and 27-100

27-401 MSE Capstone Course I

Fall: 6 units
This is the first of 2 course that together fulfill the Capstone requirement. This capstone course introduces the student to the methodology used for projects and teams based research as practiced in the Materials Science and Engineering workplace. This is a project course that requires the knowledge relationship among processing, structure, and performance to address an important contemporary problem in materials science and engineering. Student taking this course will work in a team environment to complete a design project to resolve scientific and engineering issues relating to materials. Research topics will be selected from a list of material problems or research concepts generated from companies or academia - industry research partnerships. This course will establish the research goals, review applicable research methodologies, introduce project management skills and discuss ethical concepts as teams assemble and set their research directions. On the topic selected, the work product is a report that provides clear definition of the problem being addressed, sets out a methodology for the research, includes a literature review, and reports early experimentation results and provides recommendations for future work.
Prerequisites: 27-367 and (27-305 or 27-205) and 27-301

27-402 MSE Capstone Course II

Spring: 6 units
This is the spring extension of 27-401. Teams or team members that have the industry agreement and that wish to continue their research project may do so in this course. As with 27-401, all research is expected to be original, and proper scientific ethics, and methodologies are enforced for the research and reports. Team participation and communication is an important issue and the presentation and reports must be technical and professional in structure. The course requires full project management and accounting for the research being conducted. On the topic selected, the work product is a report that provides clear definition of the problem being addressed, a methodology for the research, literature review, experimentation and reporting of findings, conclusions based on findings, and recommendations for future work.
Prerequisite: 27-401

27-406 Sustainable Materials

Fall and Spring: 9 units
This course is intended to instill a sense of how materials properties and performance are conceived and brought to market specifically under sustainability constraints arising from the increasing demand of materials, Students will be introduced to the global nature of materials and will explore the global influences on the materials supply and value chains. The student will explore issues through the framework of the materials lifecycle including resource availability, manufacturing choices, and disposable options for materials in light of their use and selection for application. As a result, the student will be able to make more informed material selection or be able to use this information to identify critical research directions for future material development.

27-410 Computational Techniques in Engineering

Spring: 12 units
This course develops the methods to formulate basic engineering problems in a way that makes them amenable to computational/numerical analysis. The course will consist of three main modules: basic programming skills, discretization of ordinary and partial differential equations, and numerical methods. These modules are followed by two modules taken from a larger list: Monte Carlo-based methods, molecular dynamics methods, image analysis methods, and so on. Students will learn how to work with numerical libraries and how to compile and execute scientific code written in Fortran-90 and C++. Students will be required to work on a course project in which aspects from at least two course modules must be integrated.
Prerequisites: 21-120 and 21-122 and (15-110 or 15-112 or 15-122) and 21-260 and 21-259

27-421 Processing Design

Fall: 6 units
In this course, the concepts of materials and process design are developed, integrating the relevant fundamental phenomena in a case study of a process design. The course includes basic science and engineering as well as economic and environmental considerations. The case study is on environmentally acceptable sustainable steelmaking. Other case studies in materials processing could be used.

27-432 Electronic and Thermal Properties of Metals, Semiconductors and Related Devices

Intermittent: 9 units
Fall odd years: This is Part I of a two-part course (Part II is 27-433) sequence concerned with the electrical, dielectric, magnetic and superconducting properties of materials. Students taking Part I will develop an in-depth understanding, based on the modern theories of solids, of the electrical, electronic and thermal properties of metals and semiconductors and the principles of operation of selected products and devices made from these materials. Overarching and interrelated topics will include elementary quantum and statistical mechanics, relationships between chemical bonds and energy bands in metals and semiconductors, the roles of phonons and electrons in the thermal conductivity of solids, diffusion and drift of electrons and holes, the important role of junctions in the establishment and control of electronic properties of selected metal- and semiconductor-based devices. Examples of commercial products will be introduced to demonstrate the application of the information presented in the text and reference books and class presentations. Additional topics will include microelectro-mechanical systems and nanoelectronics.

27-433 Dielectric, Magnetic, Superconducting Properties of Materials & Related Devices

Intermittent: 9 units
Fall even years: 9 units This is Part II of a two-part course sequence (Part I is 27-432) concerned with the electrical, dielectric, magnetic and superconducting properties of materials. Students taking Part II will develop an in-depth understanding, based on the modern theories of solids, of the dielectric, magnetic and superconducting properties of materials and the principles of operation of selected products and devices made from these materials. Topics will include relationships between chemical bonds and energy bands in dielectric and magnetic materials; polarization mechanisms in materials and their relationship to capacitance, piezoelectricity, ferroelectricity, and pyroelectricity; magnetization and its classification among materials; magnetic domains; soft and hard magnets; and the origin, theory and application of superconductivity. Examples of commercial products will be introduced to demonstrate the application of the information presented in the text and reference books and class presentations.

27-445 Structure, Properties and Performance Relationships in Magnetic Materials

Spring: 9 units
This course introduces the student to intrinsic properties of magnetic materials including magnetic dipole moments, magnetization, exchange coupling, magnetic anisotropy and magnetostriction. This is followed by discussion of extrinsic properties including magnetic hysteresis, frequency dependent magnetic response and magnetic losses. This will serve as the basis for discussing phase relations and structure/properties relationships in various transition metal magnetic materials classes including iron, cobalt and nickel elemental magnets, iron-silicon, iron-nickel, iron-cobalt and iron platinum. This will be followed by a discussion of rare earth permanent magnets, magnetic oxides, amorphous and nanocomposite magnets. Polymers used in Electromagnetic Interference (EMI) Absorbers applications will also be covered.

27-454 Supervised Reading

Spring
This course provides the opportunity for a detailed study of the literature on some subject under the guidance of a faculty member, usually but not necessarily in preparation for the Capstone Course, 27-401/402.

27-477 Introduction to Polymer Science and Engineering

Spring: 9 units
This survey-level course introduces the fundamental properties of polymer materials and the principles underlying the synthesis, engineering, manufacturing, and design with polymer materials. Fundamental concepts of molecular interactions and structure formation in molecular materials will be introduced and the effect of chemical composition on physical properties of polymers will be discussed. The basic principles of polymer chemistry will be introduced and discussed in the context of step- and chain-growth reactions. This is followed by an introduction to technologically relevant engineering properties of polymer materials with focus on mechanical properties, concepts of viscoelasticity and their application to polymer product engineering, a survey of relevant forming technologies as well as the effect of processing on material performance. Case studies will introduce students to the various stages of technical product development, i.e. problem analysis, material selection and processing plan. A final section will discuss polymer recycling and sustainable polymer technologies for a circular economy.
Prerequisite: 27-215

27-503 Additive Manufacturing and Materials

All Semesters: 9 units
This course will develop the understanding required for materials science and engineering for additive manufacturing. The emphasis will be on powder bed machines for printing metal parts, reflecting the research emphasis at CMU. The full scope of methods in use, however, will also be covered. The topics are intended to enable students to understand which materials are feasible for 3D printing. Accordingly, high power density welding methods such as electron beam and laser welding will be discussed, along with the characteristic defects. Since metal powders are a key input, powder-making methods will be discussed. Components once printed must satisfy various property requirements hence microstructure-property relationships will be discussed because the microstructures that emerge from the inherently high cooling rates differ strongly from conventional materials. Defect structures are important to performance and therefore inspection. Porosity is a particularly important feature of 3D printed metals and its occurrence depends strongly on the input materials and on the processing conditions. The impact of data science on this area offers many possibilities such as the automatic recognition of materials origin and history. Finally the context for the course will be discussed, i.e. the rapidly growing penetration of the technology and its anticipated impact on manufacturing.

27-505 Exploration of Everyday Materials

Spring: 9 units
This course is developed for upper level undergraduate and master level students outside of the College of Engineering that wish to learn about materials by experientially exploring a material and or an application of a material. Each year the course will select a material that through its' application, presents and opportunity or a concern in service. It will engage the students with studio-based exploration of the material and application, the selection criteria applicable, and engineering principles that influence the performance. It will explore a wide range of influential topics constraining material selection including societal concerns about materials and global sustainability.

27-508 Special Topics: Principles of Digital Twins in Material Science and Advanced Man

Intermittent: 9 units
This course introduces students to the concept of Digital Twins and provides a thorough introduction to digital twin modeling. An emphasis is placed on improving student literacy across digital twin capabilities and requirements so that students can navigate and understand the scope and applicability of the AI-predictive analytics lifecycle interdependencies supporting digital twins. Students learn not only how to generate and use digital twin models but also how to appropriately select digital environments given specific project requirements.

27-514 Bio-nanotechnology: Principles and Applications

Spring: 9 units
"Have you ever wondered what is nanoscience and nanotechnology and their impact on our lives? In this class we will go through the key concepts related to synthesis (including growth methodologies and characterizations techniques) and chemical/physical properties of nanomaterials from zero-dimensional (0D) materials such as nanoparticles or quantum dots (QDs), one-dimensional materials such as nanowires and nanotubes to two-dimensional materials such as graphene. The students will then survey a range of biological applications of nanomaterials through problem-oriented discussions, with the goal of developing design strategies based on basic understanding of nanoscience. Examples include, but are not limited to, biomedical applications such as nanosensors for DNA and protein detection, nanodevices for bioelectrical interfaces, nanomaterials as building blocks in tissue engineering and drug delivery, and nanomaterials in cancer therapy."

27-515 Introduction to Computational Materials Science

Fall: 9 units
This course introduces students to the theory and practice of computational materials science from the electronic to the microstructural scale. Both the underlying physical models and their implementation as computational algorithms will be discussed. Topics will include: Density functional theory Molecular dynamics Monte Carlo methods Phase field models Cellular automata Data science Coursework will utilize both software packages and purpose-built computer codes. Students should be comfortable writing, compiling, and running simple computer programs in C, C++, Fortran, MatLab, Python, or comparable environment. THIS COURSE IS FOR MSE UNDERGRADUATE STUDENTS ONLY.

27-520 Tissue Engineering

Spring: 12 units
This course will train students in advanced cellular and tissue engineering methods that apply physical, mechanical and chemical manipulation of materials in order to direct cell and tissue function. Students will learn the techniques and equipment of bench research including cell culture, immunofluorescent imaging, soft lithography, variable stiffness substrates, application/measurement of forces and other methods. Students will integrate classroom lectures and lab skills by applying the scientific method to develop a unique project while working in a team environment, keeping a detailed lab notebook and meeting mandated milestones. Emphasis will be placed on developing the written and oral communication skills required of the professional scientist. The class will culminate with a poster presentation session based on class projects. Pre-requisite: Knowledge in cell biology and biomaterials, or permission of instructor

27-533 Principles of Growth and Processing of Semiconductors

Fall: 6 units
Development of a fundamental understanding of material principles governing the growth and processing of semiconductors. Techniques to grow and characterize bulk crystals and epitaxial layers are considered. The processing of semiconductors into devices and the defects introduced thereby are discussed. The roles of growth- and processing-induced defects in determining long term reliability of devices are examined.

27-537 Data Analytics for Materials Science

Spring: 9 units
Materials Science and Engineering has traditionally been taught by emphasizing the development and application of technology. This course will present an alternative approach that combines data analytics and machine learning with material fundamentals (i.e. materials informatics). Prerequisites: 19-250 or 36-220

27-542 Thin Film Technologies

Fall: 9 units
This course will provide you with an understanding of the general science and technology involved in the production of solid thin films, the characteristics of thin film growth processes, methods to characterize important properties of thin films, and some of their current applications, particularly with regard to alternative energy sources, energy-efficient technologies and biosensing technologies. The class will include hands-on experience with thin film production, characterization and device fabrication (and characterization).

27-555 Materials Project I

Fall
This course is designed to give experience in individualized research under the guidance of a faculty member. The topic is selected by mutual agreement, and will give the student a chance to study the literature, design experiments, interpret the results and present the conclusions orally and in writing. Students must have a faculty advisor lined up prior to adding this class.

27-556 Materials Project II

Spring
Second semester of Materials Project. This course is designed to give experience in individualized research under the guidance of a faculty member. The topic is selected by mutual agreement, and will give the student a chance to study the literature, design experiments, interpret the results and present the conclusions orally and in writing.

27-561 Kinetics of Metallurgical Reactions and Processes

Fall: 6 units
This class uses examples from the ironmaking and steelmaking to illustrate different rate-determining reaction steps. Reaction times in ironmaking and steelmaking process vary quite widely; the fundamental origins of the large differences in reaction time are analyzed, after a brief overview of the main reactions and process steps in ironmaking and steelmaking. Particular skills to be practiced and developed include derivation of the mathematical relationships which describe the rates of metallurgical processes which involve heat transfer, and mass transfer for solid-gas, liquid-gas and liquid-liquid reactions; quantifying the expected rates of such reactions; identification of rate-determining steps, based on calculated rates and observed reaction rates; predicting the effects of process parameters such as particle size, stirring, temperature and chemical compositions of phases on the overall rate; and critical evaluation of kinetic data and models in scientific papers on metallurgical reactions.

27-565 Nanostructured Materials

Intermittent: 9 units
This course is an introduction to nanostructured materials or nanomaterials. Nanomaterials are objects with sizes larger than the atomic or molecular length scales but smaller than microstructures with at least one dimension in the range of 1-100 nm. The physical and chemical properties of these materials are often distinctively different from bulk materials. For example, gold nanoparticles with diameters ~15 nm are red and ~40 nm gold nanoparticles are purple whereas bulk gold has a golden color. The course starts with a discussion of top-down and bottom-up fabrication methods for making nanostructures as well as how to image and characterize nanomaterials including scanning probe microscopies. Emerging nanomaterials such as fullerenes, graphene, carbon nanotubes, quantum dots and nanocomposites are also discussed. The course then focuses on applications of nanomaterials to microelectronics, particularly nanoscale devices and the emerging field of molecular-scale electronics. The miniaturization of integrated systems that sense mechanical or chemical changes and produce as electrical signal is presented. The principles and applications of the quantum confinement effects on optical properties are discussed, mainly as sensors. The last part of the course is a discussion of nanoscale mechanisms in biomimetic systems and how these phenomena are applied in new technologies including molecular motors.

27-570 Polymeric Biomaterials

Spring: 12 units
This course will cover aspects of polymeric biomaterials in medicine from molecular principles to device scale design and fabrication. Topics include the chemistry, characterization, and processing of synthetic polymeric materials; cell-biomaterials interactions including interfacial phenomena, tissue responses, and biodegradation mechanisms; aspects of polymeric micro-systems design and fabrication for applications in medical devices. Recent advances in these topics will also be discussed.

27-577 Advanced Polymer Science and Engineering

Fall: 9 units
This advanced-level course introduces the physical concepts necessary to understand the structure-processing-properties relationships of polymers in the solid state. Chain models fundamental to the description of polymers will be introduced. The structure of solid-state polymers will be discussed with focus on the amorphous, crystalline and liquid-crystalline state. The glass transition in amorphous polymers as well as the morphology and kinetics of crystal formation in semi-crystalline polymers will be discussed in detail. Mechanical properties of polymers will be discussed with emphasis of network elasticity and linear viscoelastic behavior. Models to describe nonlinear deformation will be introduced. Simplified and viscoelastic flow models as well as the solidification of polymers will be discussed and their relevance to polymer processing illustrated. Anisotropy development during processing and the application of symmetry concepts to deduce microstructure in processed parts will be discussed. A final section of the class will be dedicated to polymer blends. Basic concepts of lattice models will be introduced and applied to predict the phase behavior of polymer blends. Applications of polymer blends, including thermoplastic elastomers and rubber toughening will be discussed.
Prerequisite: 27-477

27-591 Mechanics of Materials

Fall: 9 units
This course connects the applied loading and displacement on the materials to their internal stress and strains. We will cover failure criteria such as yield criteria and fracture mechanics. The macroscale problem will be connected to microstructure and atomistic scale features when necessary.

27-592 Solidification Processing

Intermittent: 9 units
Spring odd years: The goal of this course is to enable the student to solve practical solidification processing problems through the application of solidification theory. The objectives of this course are to: (1) Develop solidification theory so that the student can understand predict solidification structure; (2) Develop a strong understanding of the role of heat transfer in castings; (3) Develop an appreciation for the strengths and weaknesses of a variety of casting processes. The first half of the course will be theoretical, covering nucleation, growth, instability, solidification microstructure: cells, dendrites, eutectic and peritectic structures, solute redistribution, inclusion formation and separation, defects and heat transfer problems. The second part of the course will be process oriented and will include conventional and near net shape casting, investment casting, rapid solidification and spray casting where the emphasis will be on process design to avoid defects.

27-700 Energy Storage Materials and Systems

Fall and Spring: 12 units
Contemporary energy needs require energy storage and conversion for a range of mobile and stationary applications. This course will examine electrochemically functional materials, devices, and systems that are used to convert, store, and release electrical energy. The principles and mathematical models of electrochemical energy conversion and storage will be examined in depth; students will study thermodynamics and reaction kinetics pertaining to electrochemical reactions, phase transformations, transport, and processing relating to a wide range of related technologies. This course also will also cover the practical aspects associated with the application of batteries, fuel cells, supercapacitor technologies. Students are asked to conduct a class project that involves interacting with outside industry and culminates in a end-of-semester poster session.

27-703 Additive Manufacturing and Materials

All Semesters: 12 units
This course will develop the understanding required for materials science and engineering for additive manufacturing. The emphasis will be on powder bed machines for printing metal parts, reflecting the research emphasis at CMU. The full scope of methods in use, however, will also be covered. The topics are intended to enable students to understand which materials are feasible for 3D printing. Accordingly, high power density welding methods such as electron beam and laser welding will be discussed, along with the characteristic defects. Since metal powders are a key input, powder-making methods will be discussed. Components once printed must satisfy various property requirements hence microstructure-property relationships will be discussed because the microstructures that emerge from the inherently high cooling rates differ strongly from conventional materials. Defect structures are important to performance and therefore inspection. Porosity is a particularly important feature of 3D printed metals and its occurrence depends strongly on the input materials and on the processing conditions. The impact of data science on this area offers many possibilities such as the automatic recognition of materials origin and history. Finally the context for the course will be discussed, i.e. the rapidly growing penetration of the technology and its anticipated impact on manufacturing.

27-704 Principles of Surface Engineering and Industrial Coatings

Fall and Spring: 6 units
Many modern technologies rely on the use of innovative, multi-functional coatings to ensure competitive advantage in the fast-changing global markets. Building such coatings requires advanced planning of the entire coating-substrate system, and of the manufacturing steps. This course will discuss the design principles of multi-functional coatings, present advanced coating architectures and review the relevant manufacturing steps. The course will be illustrated with design principles of functional coatings in three major industries: aerospace, automotive, and machining. We will identify the relevant key challenges, and follow the thinking process of the industry leaders addressing the challenge. Then, we will examine the developed coating solutions: multi-functional tribological coatings on cutting tools; thermal barrier coatings on nickel alloy turbine blades for aircraft and power generation; diamond like coatings and wear protective coatings for automotive diesel engines; and corrosion protection in the aerospace and in the automotive industries. The course will conclude with a discussion of new trends in surface engineering and in the design of multi-functional coatings, including self-healing, self-cleaning, and other smart coatings.

27-706 Hard and Superhard Materials

Fall and Spring: 6 units
This course will focus on the fundamental principles of hard and superhard materials. We will first discuss the origin of hardness across materials, and then describe important examples of materials prized for their intrinsic or extrinsic hardness. We will focus on the preparation, microstructure, and properties of materials such as diamond, cubic boron nitride and compound carbides. Then, we will emphasize the design of novel nano-structured and nano-composite materials and coatings, which are at the frontier of material science. Finally, the course will present examples of the architecture and processing methods used to generate hard materials and coatings in manufacturing automotive and aerospace industries.

27-709 Biomaterials

Fall: 12 units
This course will cover structure-processing-property relationships in biomaterials for use in medicine. This course will focus on a variety of materials including natural biopolymers, synthetic polymers, and soft materials with additional treatment of metals and ceramics. Topics include considerations in molecular design of biomaterials, understanding cellular aspects of tissue-biomaterials interactions, and the application of bulk and surface properties in the design of medical devices. This course will discuss practical applications of these materials in drug delivery, tissue engineering, biosensors, and other biomedical technologies.

27-715 Applied Magnetism and Magnetic Materials

Spring: 12 units
In this course we address the physics of magnetism of solids with emphasis on magnetic material properties and phenomena which are useful in various applications. The content of this course includes the origins of magnetism at the atomic level and the origins of magnetic ordering (ferro-, ferri-, and antiferromagnetism), magnetic anisotropy, magnetic domains, domain wall, spin dynamics, and transport at the crystalline level. The principles of magnetic crystal symmetry are utilized to explore the various domains in ferromagnetic crystals, and tensors are used in the description of such magnetic properties as magnetocrystalline anisotropy, susceptibility and magnetostriction. To a limited extent, the applications of magnetism are discussed in order to motivate the understanding of the physical properties and phenomena.

27-719 Computational Thermodynamics

Spring: 6 units
Computational thermodynamics is a powerful tool of a Materials Engineer. We will examine how thermodynamic simulation software outputs an equilibrium calculation from a list of input conditions. This requires a description of Gibbs energy minimization calculations, Gibbs energy models, and the construction of these models from thermodynamic data. At the end of the class students should be able to use thermodynamic simulation software to solve engineering problems while recognizing its limitations. This class is for graduate students interested in these computational tools.

27-720 Tissue Engineering

Spring: 12 units
This course will train students in advanced cellular and tissue engineering methods that apply physical, mechanical and chemical manipulation of materials in order to direct cell and tissue function. Students will learn the techniques and equipment of bench research including cell culture, immunofluorescent imaging, soft lithography, variable stiffness substrates, application/measurement of forces and other methods. Students will integrate classroom lectures and lab skills by applying the scientific method to develop a unique project while working in a team environment, keeping a detailed lab notebook and meeting mandated milestones. Emphasis will be placed on developing the written and oral communication skills required of the professional scientist. The class will culminate with a poster presentation session based on class projects. Pre-requisite: Knowledge in cell biology and biomaterials, or permission of instructor

27-721 Processing Design

Fall: 6 units
In this course, the concepts of materials and process design are developed, integrating the relevant fundamental phenomena in a case study of a process design. The course includes basic science and engineering as well as economic and environmental considerations. The case study is on environmentally acceptable sustainable steelmaking. Other case studies in materials processing could be used.

27-729 Solid State Devices for Energy Conversion

Intermittent: 6 units
Intensive research efforts have yielded promising new materials approaches to 'alternative' energy conversion technologies, such as solar cells or photovoltaics; thermoelectric materials, which convert waste heat to electricity; metal/semiconductor superlattices for thermionic energy conversion; and fuel cells. At the same time, notable advances have been made in devices that substantially enhance our energy efficiency: e.g., chemical sensors and light-emitting diodes for solid-state lighting. In all of these devices, interfaces between dissimilar materials often govern and/or limit the behavior. In addition to the basic structures and operating principles, this course will cover practical materials interface issues, such as electrical transport, thermal stability, contact resistance, and bandgap engineering, that significantly affect the performance of a variety of energy conversion and energy-saving devices.

27-731 Texture, Microstructure & Anisotropy

Intermittent: 6 units
The purpose of Texture, Microstructure and amp; Anisotropy is to acquaint the student with a selected set of characterization tools relevant to the quantification of microstructure (including crystallographic orientation, i.e. texture) and anisotropic properties. The motivation for the course is problem solving in the areas of property measurement (e.g. grain boundary energy), prediction of microstructural evolution (e.g. in grain growth and recrystallization), and prediction of properties based on measured microstructure (e.g. anisotropy of work hardening and ductility). In this 6 unit mini version of the course, the specific objectives are to develop skills and understanding in the following areas: (1) The mathematical basis for crystallographic orientation distributions (aka ODFs), with explanations of the many representations of rotations/orientations; (2) Crystallographic preferred orientation (texture) and its representation by pole figures, inverse pole figures and orientation distributions, with a particular emphasis on the effects of symmetry in representations; (3) Methods of measuring texture such as X-ray (diffraction) Pole Figures and Electron Back Scatter Diffraction (EBSD) with reference to orientation mapping; (4) The effect of texture on elastic and plastic anisotropy in polycrystals; the uniform stress model (Sachs), the Taylor-Bishop and amp; Hill model, the Eshelby analysis; Emphasis is placed on the use and understanding of quantitative tools for texture data acquisition and amp; analysis (e.g. orientation distribution determination from pole figure data, and automated electron back-scatter diffraction/EBSD/OIM), the effect of crystal and sample symmetry on distributions and their representation, and the prediction of anisotropy (e.g. calculation of yield surfaces for plastic deformation). Since the datasets are often large, such as from EBSD scans, computer programs are essential.

27-734 Methods of Computational Materials Science

Fall: 12 units
This course introduces students to the theory and practice of computational materials science from the electronic to the microstructural scale. Both the underlying physical models and their implementation as computational algorithms will be discussed. Topics will include: Density functional theory Molecular dynamics Monte Carlo methods Phase field models Cellular automata Data science Examples and homework problems will be taken from all areas of materials science. Coursework will utilize both software packages and purpose-built computer codes. Students should be comfortable writing, compiling, and running simple computer programs in MatLab, Python, or comparable environment.

27-737 Data Analytics and Machine Learning for Materials Science

Intermittent: 12 units
Materials Science and Engineering has traditionally been taught by emphasizing the development and application of technology. This course will present an alternative approach that combines data analytics and machine learning with material fundamentals (i.e. materials informatics).

27-741 Practical Methods in Transmission Electron Microscopy

Fall and Spring: 12 units
This course is designed to provide instrument training on transmission electron microscopes in the Materials Characterization Facility (MCF). Emphasis will be placed on acquiring the basic skills needed to successfully operate this type of microscope; this will be achieved by a combination of lectures and hands-on lab sessions. Lectures will provide the necessary background to understand electron scattering techniques, including electron diffraction, bright field and dark field imaging, phase contrast microscopy, and energy dispersive x-ray spectroscopy. Lab sessions will inform the student on standard operating procedures for the techniques discussed in the lecture portion of the course. At the end of the course, the student is expected to demonstrate the ability to independently use the transmission electron microscope for basic operations; successful demonstration of such skills will lead to certification for day-use of transmission electron microscopes in the MCF.

27-752 Fundamentals of Semiconductors and Nanostructures

Spring: 12 units
This course is designed to provide students with a foundation of the physics required to understand nanometer-scale structures and to expose them to different aspects of on-going research in nanoscience and nanotechnology. Illustrative examples will be drawn from the area of semiconductor nanostructures, including their applications in novel and next-generation electronic, photonic, and sensing devices. The course begins with a review of basic concepts in quantum physics (wave-particle duality, Schr and #246;dinger's equation, particle-in-a-box, approximation methods in quantum mechanics, etc.) and then continues with a discussion of bulk three-dimensional solids (band structure, density of states, the single-electron effective-mass approximation). Size effects due to nanometer-scale spatial localization are then discussed within a quantum-confinement model in one-, two-, and three- dimensions for electrons. An analogous discussion for photons is also presented. The basic electronic, optical, and mechanical properties of the low-dimensional nanostructures are then discussed. A select number of applications in electronics, photonics, biology, chemistry, and bio-engineering will be discussed to illustrate the range of utility of nanostructures. Upon completion of the course, students will have an appreciation and an understanding of some of the fundamental concepts in nanoscience and nanotechnology. The course is suitable for first-year graduate students in engineering and science (but advanced undergraduates with appropriate backgrounds may also take it with permission from the instructor). Pre-requisites include 09-511, 09-701, 09-702, 18-311, 27-770, 33-225, 33-234 or familiarity with the material or basic concepts covered in these courses.

27-754 Mechanical Behavior of Engineering Materials

Intermittent: 12 units
Engineers employ all classes of materials (metals, polymers, ceramics and hybrids) in load-bearing applications. To reduce material cost, save energy and maximize performance, engineering materials are frequently designed to be used near their load-bearing limits. An understanding of underlying deformation mechanisms complements a design rule approach in that unexpected failures can be far better anticipated and hence minimized. This course will survey the major deformation mechanisms in the main materials classes. Topics will include structure, elasticity, continuum failure models, fracture mechanics, and plastic deformation mechanisms of polymers, fiber-reinforced, composites, ceramics and metals. Proper design practice and real-life failures will be discussed.

27-761 Kinetics of Metallurgical Reactions and Processes

Fall: 6 units
This class uses examples from the ironmaking and steelmaking to illustrate different rate-determining reaction steps. Reaction times in ironmaking and steelmaking process vary quite widely; the fundamental origins of the large differences in reaction time are analyzed, after a brief overview of the main reactions and process steps in ironmaking and steelmaking. Particular skills to be practiced and developed include derivation of the mathematical relationships which describe the rates of metallurgical processes which involve heat transfer, and mass transfer for solid-gas, liquid-gas and liquid-liquid reactions; quantifying the expected rates of such reactions; identification of rate-determining steps, based on calculated rates and observed reaction rates; predicting the effects of process parameters such as particle size, stirring, temperature and chemical compositions of phases on the overall rate; and critical evaluation of kinetic data and models in scientific papers on metallurgical reactions.

27-766 Defects and Diffusion in Materials

Fall: 12 units
Defects in materials, and the transport of matter through these defects by diffusion, strongly influence a material's physical properties and microstructural evolution. For example, the strength of materials, the electrical and optical properties of materials, and the rates at which microstructures coarsen, recrystallize, and oxidize all depend on the population of intrinsic and extrinsic defects and the transport of matter through these defects. The objective of this course is to define methods of quantifying the population and properties of defects in materials and the transport of matter through these defects. The course addresses both crystalline, semicrystalline, and amorphous materials and begins with the fundamentals of diffusion in amorphous materials. After describing point defect formation and equilibrium defect populations in elements and compounds, diffusion through these defects will be described. Point defect diffusion will be illustrated using examples such as the Kirkendall effect and diffusive creep. The properties and characteristics of dislocations, their motion, and the role of dislocations in deformation will also be discussed. Short circuit diffusion and the role of diffusion in dislocation creep will be described as examples of transport involving dislocations. Finally, the energetics of planar defects, grain boundaries, and interfaces will be discussed. Diffusive transport along interfaces will be described, using examples including transport in two phase systems, sintering, and coarsening.

27-791 Mechanical Behavior of Materials

Spring: 12 units
This course connects the applied loading and displacement on the materials to their internal stress and strains. We will cover failure criteria such as yield criteria and fracture mechanics. The macroscale problem will be connected to microstructure and atomistic scale features when necessary.

27-792 Solidification Processing

Spring: 12 units
The goal of this course is to enable the student to solve practical solidification processing problems through the application of solidification theory. The objectives of this course are to: (1) Develop solidification theory so that the student can understand predict solidification structure; (2) Develop a strong understanding of the role of heat transfer in castings; (3) Develop an appreciation for the strengths and weaknesses of a variety of casting processes. The first half of the course will be theoretical, covering nucleation, growth, instability, solidification microstructure: cells, dendrites, eutectic and peritectic structures, solute redistribution, inclusion formation and separation, defects and heat transfer problems. The second part of the course will be process oriented and will include conventional and near net shape casting, investment casting, rapid solidification and spray casting where the emphasis will be on process design to avoid defects.

27-796 Structure and Characterization of Materials

Fall: 12 units
The objective of this course is for the student to be able to understand important crystal structures of both inorganic and organic materials in terms of their building blocks (atom positions, Bravais lattices, structural units, symmetry groups, stacking and packing configurations) and also to understand how modern experimental materials characterization techniques (including x-ray, electron, and neutron diffraction and spectroscopic techniques) are used to obtain structural and chemical information.

27-798 Thermodynamics of Materials

Fall: 12 units
This course offers a practical introduction to the principles of statistical thermodynamics that links the microscopic atomic details of materials to their macroscopic behavior, and applies these principles to multicomponent material equilibria. The laws and concepts of classical thermodynamics and probability are briefly reviewed, and then applied to introduce the atomic statistical definitions for temperature, entropy, and thermodynamic equilibrium. Statistical methods for enumerating the microscopic configurations of fluids, magnets, solid crystals, and polymers will be covered and applied to evaluate thermodynamic free energies subject to varying macroscopic constraints. These will be used to relate equilibrium properties and phase behavior to the engineerable molecular details of materials. Applications will include equilibrium phase diagrams (binary and ternary), predominance diagrams, chemical reactions, thermodynamics of surfaces, and electrochemistry.

27-990 SPECIAL TOPICS: Teaching Materials Science & Engineering

Spring: 3 units
This course is designed to prepare graduate students for their future role as educators in Materials Science and amp; Engineering. Teaching is a critical facet of higher education whether as a course assistant, instructor, or student mentor. Although excellent teaching can have a significant positive impact on students at all levels, formal training at the University level is relatively uncommon. Contrary to popular belief, teaching is not simply a skill you are born with, but rather one that requires significant practice and continuous refinement. The primary goal of this course is to provide pedagogical strategies necessary to be an effective teacher with a focus on fundamental topics in materials science and amp; engineering.

Department of Mechanical Engineering

Jonathan Cagan,
Department Head and George Tallman and Florence Barrett Ladd Professor in Engineering

Location: Scaife Hall 336
www.cmu.edu/me (http://www.cmu.edu/me/)

General Overview

Mechanical engineers use their knowledge of mechanical systems to describe phenomena, propose solutions to problems, and build those solutions. Concerned with the principles of force, energy and motion, they use their knowledge of physical systems, design, manufacture, and operational processes to advance the world around us. Mechanical engineers work in a variety of sectors: small start-up companies, multi-national corporations, government agencies, national laboratories, consulting firms, and universities.

The Carnegie Mellon Mechanical Engineering curriculum emphasizes engineering theory, hands-on experience, and technical skills. Our students learn how to solve practical problems and analyze situations by converting ideas into reliable and cost-effective devices and processes.

A strong foundation in mechanical engineering fundamentals culminates in a design capstone class where student teams develop prototypes for new products. These projects expose students to the design process, from concept to product, and emphasize effective communication and presentations skills.

Our curriculum is intended to allow ample opportunity for students to pursue areas of personal interest. A student may choose to pursue a minor offered by departments in other colleges, or one of the designated minor programs offered in the College of Engineering, or to pursue an additional major. Students are encouraged to participate in research with department faculty members, explore their chosen field through internships, and take advantage of opportunities to study abroad and be exposed to other cultures. Students may also choose to pursue the Integrated Master’s/Bachelor’s Program (IMB) which allows students to earn both a bachelor’s and a master’s degree with an additional semester or year of study.

Mechanical Engineering students access TechSpark (https://engineering.cmu.edu/techspark/) for hands-on projects in multiple core courses and technical electives. TechSpark (https://engineering.cmu.edu/techspark/) is the cornerstone of the College of Engineering's maker ecosystem, where students are advised by faculty and staff to create, develop, and test new ideas for technology innovation. The space houses a computer simulation cluster, 3D printers, laser machines, electronics stations, manual lathes & CNC mills, metal welding, wood working & CNC Router, polymer composite fabrication, paint booth, and more. This integrated set of resources allows students, faculty, and staff to design and prototype in a multi-disciplinary environment.

Accreditation

The Mechanical Engineering program is accredited by the Engineering Accreditation Commission of ABET, https://www.abet.org, under the General Criteria and the Program Criteria for Mechanical and Similarly Named Engineering Programs.

Program Educational Objectives

According to ABET (http://www.abet.org/), which evaluates applied science, computing, engineering and technology programs for accreditation, “program educational objectives are broad statements that describe what graduates are expected to attain within a few years of graduation.”

The core objective of our undergraduate program is to provide our students an education that enables them to be productive, impactful, and fulfilled professionals throughout their careers. In light of this vision, the program educational objectives of the Bachelor of Science in Mechanical Engineering at Carnegie Mellon are to produce graduates who:

- Distinguish themselves as effective problem solvers by applying fundamentals of mechanical engineering alongside modern experimental and computational methods
- Are innovative and resourceful in their professional activities.
- Excel in team settings, incorporating diverse viewpoints and ideas and implementing strategies for equitable participation
- Become effective communicators who are prepared to take on leadership roles in their organizations, their profession, and in society
- Conduct themselves in a professional and ethical manner in the workplace.
- Excel in diverse career paths within and beyond engineering profession, including in industry and academia.

student Outcomes

The undergraduate curriculum in the Department of Mechanical Engineering offers students significant opportunities to pursue directions of personal interest, including minors, double majors, participation in research projects, and study abroad. Design and teamwork experiences occur at regular intervals in the curriculum, and graduates have significant hands-on experience through laboratories and projects.

Carnegie Mellon's Mechanical Engineering faculty members are in support of the following set of skills and outcomes put forth by ABET:

- an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
- an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
- an ability to communicate effectively with a range of audiences
- an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
- an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
- an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
- an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

Curriculum

Minimum units required for B.S. in Mechanical Engineering: 382

The following template outlines the four-year B.S. program through the standard and recommended course sequence. To ensure that prerequisites are completed and to prevent scheduling conflicts, students should discuss any changes to this sequence with their department academic advisor. Students need a minimum of 382 units to complete the B.S. degree. Since there are variable units for some core requirements, additional units can be made up with free electives.

First Year

Fall		Units
21-120	Differential and Integral Calculus	10
24-101	Fundamentals of Mechanical Engineering	12
33-141	Physics I for Engineering Students	12
99-101	Core@CMU	3
76-101	Interpretation and Argument	9
		46

Spring		Units
21-122	Integration and Approximation	10
xx-xxx	Second Introductory Engineering Course	12
xx-xxx	Physics II/Computer Science/Chemistry*	10-12
xx-xxx	General Education Course	9
		41-43

First Year Curriculum Notes:

1. During the first year, students complete 24-101 Fundamentals of Mechanical Engineering and one other introductory engineering

course. 24-101 Fundamentals of Mechanical Engineering is a prerequisite for sophomore courses 24-261 Mechanics I: 2D Design and 24-251 Electronics for Sensing and Actuation, as well as junior course 24-351 Dynamics. Students who are not able to take 24-101 in their first year will push the 24-261 Mechanics I and 24-262 Mechanics II sequence into their junior year. If 24-101 is taken in fall of sophomore year, students can take 24-251 Electronics for Sensing and Actuation and 24-351 Dynamics in sophomore spring to continue progress towards the Mechanical Engineering degree.

2. All Mathematics courses (21-xxx) required for the engineering degree must have a minimum grade of C in order to fulfill the graduation requirement for the BS engineering degree and to count as a prerequisite for engineering core classes.
3. Students must pass the following three courses before they begin the core Mechanical Engineering courses in the fall of their sophomore year:
    21-120 Differential and Integral Calculus
    21-122 Integration and Approximation

    33-141 Physics I for Engineering Students

Sophomore Year

Fall		Units
24-221	Thermodynamics	10
24-261	Mechanics I: 2D Design	10
21-254	Linear Algebra and Vector Calculus for Engineers	11
xx-xxx	Physics II/Computer Science/Chemistry*	10-12
24-xxx	24-200 Machine Shop OR 24-251 Electronics for Sensing and Actuation ** and ***	1-3
xx-xxx	General Education Course	9
39-210	Experiential Learning I	0
		51-55

Spring		Units
24-231	Fluid Mechanics	10
24-262	Mechanics II: 3D Design	10
21-260	Differential Equations	9
xx-xxx	Physics II/Computer Science/Chemistry*	10-12
24-xxx	24-200 Machine Shop OR 24-251 Electronics for Sensing and Actuation **and***	1-3
xx-xxx	Lab requirement ****	
xx-xxx	General Education Course	9
39-220	Experiential Learning II	0
		49-53

* **Physics II/Chemistry/Computer Science:**
First year students are encouraged to prioritize completing Physics II and Programming requirement over Chemistry in the first year.

- The recommended Physics sequence is 33-141 (http://coursecatalog.web.cmu.edu/search/?P=33-141) / 33-142 (http://coursecatalog.web.cmu.edu/search/?P=33-142) for engineering students, however, 33-151 (http://coursecatalog.web.cmu.edu/search/?P=33-151) / 33-152 (http://coursecatalog.web.cmu.edu/search/?P=33-152) will also meet the CIT Physics requirement.
- The programming requirement can be filled with 15-110 Principles of Computing or 15-112 Fundamentals of Programming and Computer Science.
- The Chemistry requirement can be filled with 09-105 Introduction to Modern Chemistry I or 09-111 Nanolegos: Chemical Building Blocks.

** **24-200 or 24-203 and 24-251 Completed Sophomore Year:**
Machine shop 24-200 Maker Series: Intro to Manual Machining **or** 24-203 Special Topics: TechSpark: Manual Machining **and** 24-251 Electronics for Sensing and Actuation should be completed in sophomore year. Both are required courses.

*** **Waiving Electronics for Sensing and Actuation:**
Mechanical Engineering (MechE) students who took the 18-100 Introduction to Electrical and Computer Engineering in their first year, have the option of waiving 24-251 Electronics for Sensing and Actuation. These units must be replaced with 3 units of graded Mechanical Engineering credit which could be done by taking a 12 unit MechE Technical Elective instead of a 9 unit course. Eligible students will be invited to complete a form to confirm their intention to waive 24-251.

**** **Lab Requirement:**
Mechanical engineering undergraduates must satisfy one science laboratory requirement to graduate. The lab requirement may be fulfilled with one of the following courses in any semester:

03-124	Modern Biology Laboratory	9
09-101	Introduction to Experimental Chemistry	3
33-100	Basic Experimental Physics	6
33-104	Experimental Physics	9
42-203	Biomedical Engineering Laboratory	9

Junior Year

Fall		Units
24-302	Professional Development for Mechanical Engineers Taken either Fall or Spring.	2
24-322	Heat Transfer	10
24-351	Dynamics (Offered Fall and Spring)	10
24-370	Mechanical Design: Methods and Applications	12
36-220	Engineering Statistics and Quality Control	9
xx-xxx	General Education Course	9
39-310	Experiential Learning III	0
		52

Spring		Units
24-302	Professional Development for Mechanical Engineers Taken either Fall or Spring.	2
24-311	Numerical Methods	10
24-321	Thermal-Fluids Experimentation	12
24-352	Dynamic Systems and Controls (Offered Fall and Spring)	12
xx-xxx	General Education Course	9
		45

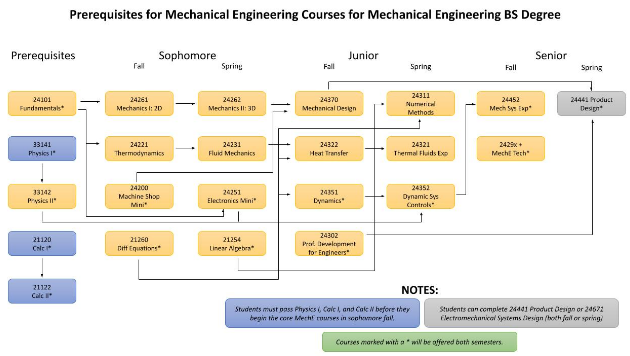
Senior Year

Fall		Units
24-441	Engineering Design II: Conceptualization and Realization ****	12
or 24-671	Electromechanical Systems Design	
24-452	Mechanical Systems Experimentation (Offered Fall and Spring)	9
xx-xxx	Elective	9
xx-xxx	Elective	9
xx-xxx	General Education Course	9
		48

Spring		Units
24-441	Engineering Design II: Conceptualization and Realization ****	12
or 24-671	Electromechanical Systems Design	
24-xxx	Mechanical Engineering Technical Elective	9-12
xx-xxx	General Education Course	9
xx-xxx	Elective	9
xx-xxx	Elective	9
		48-51

**** **Capstone Courses:**

- Mechanical Engineering students complete **one** capstone class either fall or spring of senior year. This course is the culmination of the knowledge gained over the previous years in mechanical engineering core classes. To fulfill the capstone course requirement, students can complete one of the following 24-441 Engineering Design II: Conceptualization and Realization (FALL OR SPRING), 24-671 Electromechanical Systems Design (FALL OR SPRING).
- Capstone course can be taken either Fall or Spring of senior year.
- Biomedical Engineering Double Majors **may** use the capstone for their double major **instead of** the above listed MechE capstone classes.



Mechanical Engineering Technical Electives

Students must take at least one approved non-core Mechanical Engineering course labeled as "Mechanical Engineering Technical Elective" in the example course sequence. The course must be an approved 24-xxx course (9-unit minimum) at the 300 level or above to fulfill the technical elective requirement. 24-292 Renewable Energy Engineering is the only 200 level courses that may be used as a Mechanical Engineering Technical Elective.

Students can also take mechanical engineering graduate courses to fulfill the technical elective requirement. However, students must have the appropriate prerequisites and the instructor must approve taking the course. Undergraduates do not have priority for graduate level courses. Students can find a list of graduate courses we offer on the Carnegie Mellon Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/).

Course offerings are variable, please check the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/) to see the most current list of classes.

Students cannot use research or project courses to fulfill the technical elective requirement. However, these courses, with limitations, will count as free elective units. Up to 27 units of project/research may be counted in the free electives. Project/research courses that do not fulfill the technical elective requirements are:

- 24-391 / 24-392 Mechanical Engineering Project
- 24-491 / 24-492 Department Research Honors
- 39-xxx CIT series courses

Free Electives

A Free Elective is defined as any graded course offered by any academic unit of the university. Free electives offer students the opportunity to add additional majors and minors, pursue additional interests or deepen their experience in Mechanical Engineering. Typically, once the core requirements are completed, there remain about 45 units of free electives to reach the minimum of 382 to complete the degree.

Up to 9 units of Student Taught Courses (StuCO) and Physical Education courses, or other courses taken as Pass/Fail, may also be used toward Free Electives.

Guidance on Engineering Electives

The Mechanical Engineering department offers several elective courses for undergraduates seeking further knowledge and experience in specialty areas of mechanical engineering. These courses (with approval) can fulfill for your Mechanical Engineering Technical Elective, Free Electives, and/or additional major or minor requirements.

Robotics and Automation

Fundamental Courses		
24-451	Feedback Control Systems	12
24-677	Modern Control Theory	12
24-760	Robot Dynamics and Analysis	12
24-773	Multivariable Linear Control	12
24-776	Non Linear Control	12
Application Courses		
24-614	Microelectromechanical Systems	12
24-671	Electromechanical Systems Design	12
24-673	Soft Robots: Mechanics, Design and Modeling	12
24-753	Special Topics: Robotic Materials: Designs, Principles & Mechanics	12
24-774	Advanced Control Systems Integration	12
24-775	Robot Design and Experimentation	12
24-778	Mechatronic Design	12

Energy, Environment, and Thermal Fluid Systems

Fundamental Courses		
24-711	Fluid Dynamics	12
24-718	Computational Fluid Dynamics	12
24-721	Advanced Thermodynamics	12
24-722	Energy System Modeling	12
24-730	Advanced Heat Transfer	12
Application Courses		
24-292	Renewable Energy Engineering	9
24-381	Environmental Systems on a Changing Planet	12
24-421	Internal Combustion Engines	12
24-425	Combustion and Air Pollution Control	9
24-428	Computational Analysis of Transport Phenomena	9
24-623	Molecular Simulation of Materials	12
24-626	Air Quality Engineering	12
24-628	Energy Transport and Conversion at the Nanoscale	12
24-629	Direct Solar and Thermal Energy Conversion	12
24-631	Thermal Design	12
24-643	Energy Storage Materials and Systems	12

Product Design and Development

Fundamental Courses		
24-651	Material Selection for Mechanical Engineers	12
24-681	Computer-Aided Design	12
24-683	Design for Manufacture and the Environment	12
24-688	Introduction to CAD and CAE Tools	12
Application Courses		
24-632	Special Topics: Additive Manufacturing Processing and Product Development	12
24-633	Additive Manufacturing Laboratory	12
24-672	Special Topics in DIY Design and Fabrication	12
24-680	Quantitative Entrepreneurship: Analysis for New Technology Commercialization	12
24-691	Mechanical Engineering Project Management	12
24-692	Special Topics: Engineering a Startup: How to Start and Grow a Hardware Company	12

Autonomous Systems and Machine Learning

Fundamental Courses		
24-451	Feedback Control Systems	12
24-480	Special Topics: Artificial Intelligence and Machine Learning for Engineering	9
24-677	Modern Control Theory	12
24-704	Probability and Estimation Methods for Engineering Systems	12
24-789	Special Topics: Deep Learning for Engineers	12
Application Courses		
24-774	Advanced Control Systems Integration	12
24-775	Special Topics: Robot Design and Experimentation	12
24-784	Special Topics: Trustworthy AI	12

Computational Engineering

Fundamental Courses		
24-703	Numerical Methods in Engineering	12
24-780	Engineering Computation	12
24-783	Advanced Engineering Computation	12
24-785	Engineering Optimization	12
Application Courses		
24-658	Image-Based Computational Modeling and Analysis	12
24-681	Computer-Aided Design	12

24-718	Computational Fluid Dynamics	12
24-755	Finite Elements in Mechanics I	12
24-781	Engineering Computation Project	12

Engineering Mechanisms and Materials

Fundamental Courses		
24-634	Structural Design	12
24-635	Structural Analysis	9
24-652	Mechanical Behavior of Engineering Materials	12
24-653	Special Topics: Materials and Their Processing for Mechanical Engineers	12
24-751	Solid Mechanics and Elasticity	12
Application Courses		
24-643	Energy Storage Materials and Systems	12
24-650	Applied Finite Element Analysis	12
24-684	Special Topics: Nanoscale Manufacturing Using Structural DNA Nanotechnology	12
24-755	Finite Elements in Mechanics I	12
24-753	Special Topics: Robotic Materials: Designs, Principles & Mechanics	12

Quality Point Average Requirements

To be eligible to graduate, undergraduate students must complete all course requirements for their program with a cumulative Quality Point Average of at least 2.00 for all courses taken. For undergraduate students who enrolled at Carnegie Mellon as freshmen and whose freshman grades cause the cumulative QPA to fall below 2.0, this requirement is modified to be a cumulative QPA of at least 2.0 for all courses taken after the freshman year. Note, however, the cumulative QPA that appears on the student's final transcript will be calculated based on all grades in all courses taken, including freshman year. The Mechanical Engineering Department requires that students attain a quality point average of 2.00 or higher for all required Mechanical Engineering core courses.

Pursuant to university rules, students can repeat a course in which a grade below C was attained in order to achieve the QPA requirement. When a course is repeated, all grades will be recorded on the official academic transcript and will be calculated in the student's QPA. For all required Mechanical Engineering core courses, the highest grade obtained between the original and the repeated class will be used to calculate the Mechanical Engineering QPA.

Credit Overload Policy

Mechanical Engineering students can register for a maximum of 54 units per semester. A student can request additional units from the Undergraduate Education Committee based on their QPA. The policy is outlined in the Mechanical Engineering Undergraduate Handbook (https://www.meche.engineering.cmu.edu/education/undergraduate-education/undergraduate-handbooks.html).

Additional Majors and Minors

Mechanical Engineering students may pursue additional majors and minors in a variety of subjects, taking advantage of the free elective courses to satisfy the requirements for the major or minor. The College of Engineering has added designated minors to promote flexibility and diversity among engineering students. Common double majors for Mechanical Engineering students include Engineering and Public Policy, Biomedical Engineering, Engineering Design, and Innovation & Entrepreneurship and Robotics.

A complete description of majors and minors in engineering can be found on the College of Engineering website (https://engineering.cmu.edu/education/undergraduate-studies/curriculum/).

Internships and Co-operative Education Program

The Mechanical Engineering Department considers experiential learning opportunities important educational options for its undergraduate students. Students in Mechanical Engineering are encouraged to undertake professional internships during summer breaks.

Another option is cooperative education, which provides a student with an extended period of exposure with a company. All co-ops must be at least 6 consecutive months in length, and must be a full-time, paid position with a single company.

Study Abroad

In today’s global society, a study abroad experience can be an integral part of an undergraduate engineering education. An academic experience abroad is encouraged and assistance is provided for course choices and curriculum sequencing. The Mechanical Engineering department offers scholarships for international experiences to support and encourage students to take advantage of study and work abroad experiences.

Integrated Master's/Bachelor's Program (IMB)

Interested undergraduates may plan a course of study that leads to both the Bachelor's and Master's in Mechanical Engineering. Beyond eight semesters, at least one semester of full-time graduate student status is required. Please refer to the Integrated Master’s/Bachelor’s Degree Program section in the most recent Master of Science in Mechanical Engineering Handbook (https://www.meche.engineering.cmu.edu/education/graduate-programs/handbooks.html) for additional information.

Full-Time Faculty

BURAK AKSAK, Teaching Professor – P.h.D, University of Illinois Urbana-Champaign; Carnegie Mellon, 2025–

AMIR BARATI FARIMANI, Assistant Professor of Mechanical Engineering – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2018–

MARK BEDILLION, Teaching Professor of Mechanical Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2016–

SARAH BERGBREITER, Professor of Mechanical Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2018–

JACK LEE BEUTH, Professor of Mechanical Engineering – Ph.D., Harvard University; Carnegie Mellon, 1992–

OPHELIA BOLMIN, Assistant Professor – P.h.D., University of Illinois Urbana-Champaign; Carnegie Mellon, 2024–

JONATHAN CAGAN, Department Head and George Tallman and Florence Barrett Ladd Professor of Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 1990–

MAARTEN P. DE BOER, Professor of Mechanical Engineering – Ph.D., University of Minnesota; Carnegie Mellon, 2007–

NESTOR GOMEZ, Assistant Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2018–

NOELIA GRANDE GUTIERREZ, Assistant Professor of Mechanical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2021–

DIANA HAIDAR, Assistant Teaching Professor of Mechanical Engineering – Ph.D., University of Delaware; Carnegie Mellon, 2017–

ENI HALILAJ, Assistant Professor of Mechanical Engineering – Ph.D., Brown University; Carnegie Mellon, 2018–

B. REEJA JAYAN, Associate Professor of Mechanical Engineering – Ph.D., University of Texas at Austin; Carnegie Mellon, 2015–

AARON M. JOHNSON, Assistant Professor of Mechanical Engineering – Ph.D., University of Pennsylvania; Carnegie Mellon, 2016–

TREVOR J JONES, Assistant Professor – Ph.D., Princeton University; Carnegie Mellon, 2023–

INSEUNG KANG, Assistant Professor – P.h.D., Georgia Tech; Carnegie Mellon, 2024–

LEVENT BURAK KARA, Professor of Mechanical Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2007–

PHILIP R. LEDUC, William J. Brown Professor of Mechanical Engineering – Ph.D., The Johns Hopkins University; Carnegie Mellon, 2002–

SHAWN LITSTER, Professor of Mechanical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2008–

CARMEL MAJIDI, Clarence H. Adamson Professor of Mechanical Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2011–

JONATHAN A. MALEN, Professor of Mechanical Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2009–

CHRISTOPHER MCCOMB, Associate Professor of Mechanical Engineering – Ph.D. , Carnegie Mellon University; Carnegie Mellon, 2021–

ALAN J.H. MCGAUGHEY, Trustee Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2005–

JEREMY J. MICHALEK, Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2005–

O. BURAK OZDOGANLAR, Ver Planck Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2004–

RAHUL PANAT, Russell V. Trader Career Development Associate Professor of Mechanical Engineering – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2017–

SNEHA PRABHA NARRA, Assistant Professor of Mechanical Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2021–

ALBERT PRESTO, Research Professor of Mechanical Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2012-–

YOED RABIN, Professor of Mechanical Engineering – D.Sc., Technion-Israel Institute of Technology; Carnegie Mellon, 2000–

SHENG SHEN, Professor of Mechanical Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2011–

KENJI SHIMADA, Theodore Ahrens Professor of Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1996–

SATBIR SINGH, Teaching Professor of Mechanical Engineering – Ph.D., University of Wisconsin at Madison; Carnegie Mellon, 2012–

RYAN SULLIVAN, Professor of Mechanical Engineering – Ph.D., University of California at San Diego; Carnegie Mellon, 2012–

REBECCA TAYLOR, Associate Professor of Mechanical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2016–

CONRAD TUCKER, Arthur Hamerschlag Career Development Professor of Mechanical Engineering – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2019–

LIWEI WANG, Assistant Professor – P.h.D, Shanghai Jiao Tong University; Carnegie Mellon, 2024–

DOUGLAS WEBER, Akhtar and Bhutta Professor of Mechanical Engineering – Ph.D., Arizona State University; Carnegie Mellon, 2020–

VICTORIA WEBSTER-WOOD, Assistant Professor of Mechanical Engineering – Ph.D., Case Western Reserve University; Carnegie Mellon, 2018–

KATE S. WHITEFOOT, Associate Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2016–

JESSICA ZHANG, George Tallman Ladd and Florence Barrett Ladd Professor of Mechanical Engineering – Ph.D., University of Texas at Austin; Carnegie Mellon, 2007–

DING ZHAO, Assistant Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2018–

Emeriti

ADNAN AKAY, Lord Emeritus Professor of Mechanical Engineering – Ph.D., North Carolina State University; Carnegie Mellon, 1992–

JERRY HOWARD GRIFFIN, William J. Brown Emeritus Professor of Mechanical Engineering – Ph.D., California Institute of Technology; Carnegie Mellon, 1981–

EDWARD STEPHAN RUBIN, Emeritus Professor of EPP, Mechanical Engineering, and Environmental Engineering and Science – Ph.D., Stanford University; Carnegie Mellon, 1969–

PAUL STEIF, Professor Emeritus – P.h.D., Harvard University; Carnegie Mellon, 1983–

SHI-CHUNE YAO, Emeritus Professor of Mechanical Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 1977–

Department of Mechanical Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

24-050 Study Abroad

Fall
Mechanical Engineering students studying abroad through other institutions are registered for this zero-unit place holder "course." Prior to being enrolled for study abroad, the student must have completed an Office of International Education "Study Abroad Transfer Credit (SATC) Form," which must be signed by their academic advisor in Mechanical Engineering.

24-101 Fundamentals of Mechanical Engineering

Fall and Spring: 12 units
The purpose of this course is to introduce the student to the field of mechanical engineering through an exposition of its disciplines, including structural analysis, mechanism design, fluid flows, and thermal systems. By using principles and methods of analysis developed in lectures, students will complete two major projects. These projects will begin with conceptualization, proceed with the analysis of candidate designs, and culminate in the construction and testing of a prototype. The creative process will be encouraged throughout. The course is intended primarily for CIT first year students.

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-104 TechSpark: Modern Making

Fall and Spring: 3 units
This course teaches the fundamental skills needed to plan, develop, and prototype a functional device. A significant portion of the course will cover introductory-level use of 3D CAD software, 3D printers, and Arduino. Homework assignments are important for reinforcement of skills learned, and the utilization of these skills will be applied to a self-directed project. 3-unit mini (7-weeks)

Course Website: http://www.cmu.edu/me (http://www.cmu.edu/me/)

24-105 Special Topics: Maker Series: Intro to Laser Cutting & Engraving

Fall and Spring: 1 unit
This course teaches the safe operation of the laser cutter-engraver machine through structured hands-on activities. A significant portion of this course is dedicated to learning joinery, color mapping, and material selection for prototyping. Homework assignments are important for reinforcement of skills learned, and are flexible for students to complete guided or self-directed projects. 1-unit micro (2-weeks)

24-200 Maker Series: Intro to Manual Machining

Fall and Spring: 1 unit
This course teaches safe operation of manual machining equipment through structured hands-on activities. A significant portion of the course is dedicated to learning subtractive manufacturing, the industrial standard for the mass manufacture of products around the world. The skills learned in this course can be applied to fabricate durable components for design projects, research equipment, and extracurricular activities. 1-unit mini (7-weeks)

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-201 Special Topics: TechSpark: Project Fabrication and Assembly

Fall: 1 unit
This course teaches the fundamental skills of fabrication and assembly by progressing through a hands-on building project. A significant portion of the course is dedicated to safely operating hand and power tools, using common components as parts for assemblies, and incorporating moving mechanisms within housings. This class provides a foundational experience that can be built upon in future project classes. 1-unit mini (7-weeks)

24-202 Introduction to Computer Aided Design

Fall and Spring: 1 unit
Introduction to computer aided mechanical design using SolidWorks 3D CAD software. Includes the creation and analysis of components and assemblies, generation of drawings, and exporting for manufacture. Two hours of guided computer lab work each week. Prerequisite: Undergraduate Mechanical Engineering standing
Prerequisites: 24-104 or 24-101

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-203 Special Topics: TechSpark: Manual Machining

Fall and Spring: 3 units
This course teaches the safe operation of manual machining equipment, including knee mill and lathe through structured hands-on activities. A significant portion of this course is dedicated to reading technical drawings, and then fabricating those components using equipment. Homework assignments are important for reinforcement of skills learned, and a self-directed project will utilize known techniques in new applications. This course is required to use the student machine shop at TechSpark. 3-unit mini (7-weeks)

24-204 TechSpark: Metal Jewelry

Fall and Spring: 3 units
This course teaches introductory-level metal jewelry fabrication through structured hands-on activities. Students will learn to safely use various tools and metal working techniques including cold forging, investment casting, bezel settings, soldering, and patinas. Homework assignments are important for reinforcement of skills learned, which will include creating personal jewelry items such as earrings, pendants, and rings. This course is required to use the hot metals room at TechSpark. 3-unit mini (7-weeks)

24-205 TechSpark: Welding

Fall and Spring: 2 units
This course teaches the safe operation of welding equipment through structured hands-on activities. A significant portion of the course is dedicated to learning workpiece setup, material selection, and weldability assessment for introductory-level projects. Homework assignments are important for reinforcement of skills learned, and the utilization of these skills will be applied to a self-directed project. This course is required to use the welding equipment at TechSpark. 3-unit mini (7-weeks)

24-206 TechSpark: Wood Working I

Fall and Spring: 3 units
This course teaches the safe operation of wood working equipment, including table saw, panel saw, and miter saw through structured hands-on activities. A significant portion of the course is dedicated to learning optimal workflow, tool selection, and equipment selection for introductory-level projects. Homework assignments are important for reinforcement of skills learned. This course is required to use the student wood shop at TechSpark. 3-unit mini (7-weeks)

24-207 TechSpark: Wood Working II

Fall and Spring: 1 unit
This course builds upon previous skills taught in 24-206 TechSpark: Wood Working I. A significant portion of the course is dedicated to learning wood material properties, joinery methods, and CNC router machine for mid-level projects. Homework assignments are important for reinforcement of skills learned. This course is required to use the CNC wood router in the student wood shop at TechSpark. 3-unit mini (7-weeks)
Prerequisite: 24-206

24-210 Special Topics: Maker Series: Inventive Projects

Fall and Spring
This course supports students in pursuing a self-defined project. Students will apply their preexisting access to equipment towards prototyping an inventive project, either as an individual or a group member. Students will receive weekly one-on-one consultations with the instructor to conduct project planning, design for fabrication, prototype testing, and more. This course is useful for students interested in initiating, progressing, and/or completing a prototyping project for research, student orgs, entrepreneurship, hobbies, or other interests.
Prerequisites: 24-206 or 24-205 or 24-204 or 24-200 or 24-101 or 24-105 or 24-104

24-212 Special Topics: Maker Series: Make It Move

Fall and Spring: 9 units
This course explores many types of mechanisms for movement and their optimal applications. A significant portion of class will be dedicated to hands-on labs, during which objects are dissected to reveal their methods of movement. Springs, gears, motors, pneumatics, levers, wheels, bearings, and other components will be analyzed for their roles in energy storage, power delivery, and motion. These lessons will culminate in a complete design project, for which students will use rapid fabrication equipment to make a prototype that moves.
Prerequisites: 24-101 or 24-104

Course Website: https://www.meche.engineering.cmu.edu/

24-213 Special Topics: Citizen Science: Sensors, Makers and the Environment

Spring: 9 units
This course will introduce students to technical aspects of citizen science, using air pollution as a case study. Students will learn about important air pollutants and the environmental regulations that govern these pollutants in the U.S. Students will be introduced to data quality requirements for applications ranging from regulatory pollutant monitoring to education/outreach. Students will also learn about operating principles for both laboratory- and consumer-grade pollutant monitoring equipment. The class will culminate in a project where student teams will design, construct, and test a low-cost air pollutant monitoring system. The groups will then deploy these sensor packages to collect and present their data. The project will use the TechSpark maker space. It is primarily aimed at non-engineering majors.

24-214 IDeATe Special Topics: Mazes

Fall: 9 units
Labyrinths have been a part of our culture for millennia, from Greek myths to Renaissance palaces, to childrens pastime. The mental challenge of traversing a maze combines both the intuitive and the systematic processes that delight our human experience. As our society becomes more sedentary, the rebirth of the physical maze can serve as a bridge from the pure mental exercise to increased mobility, especially if they are modernized to become more dynamic, more adaptable, more portable, more modern. This course will allow students to study the history of labyrinths and to discover how to design and build fun, challenging, technically-enhanced, and community-engaging mazes.

24-215 IDeATe Special Topics: Smart Furniture

All Semesters: 9 units
As we integrate personal technology into our daily lives, the spaces we inhabit evolve from purely functional, comfortable, and efficient locations for work, play, and relaxation to statements on our lifestyle, tastes, and self-image. Of the attributes in our spaces we can control, furniture has the greatest effect on how our living spaces reflect our personalities. This course will thus focus on the design and physical prototyping of smart, multi-use, transforming furniture that can elevate our modern living spaces to unique showcases of our individuality.

24-221 Thermodynamics

Fall: 10 units
Temperature and thermometry; equations of state for fluids and solids; work, heat, and the first law; internal energy, enthalpy, and specific heats; energy equations for flow; change of phase; the second law, reversibility, absolute temperature, and entropy; combined first and second laws; availability; power and refrigeration cycles. Applications to a wide range of processes and devices. 3 hrs. lec., 1 hour recitation
Prerequisites: (33-121 or 33-106 or 33-141 or 33-151) and 21-122 Min. grade C and 24-101

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-231 Fluid Mechanics

Spring: 10 units
Hydrostatics. Control volume concepts of mass, momentum, and energy conservation. Euler's and Bernoulli's equations. Viscous flow equations. Head loss in ducts and piping systems. Dimensional analysis and similitude as an engineering tool. Measurement techniques. 3 hrs. lec., 1 hr. rec.
Prerequisites: (33-151 or 33-141 or 33-106) and 21-122 Min. grade C

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-251 Electronics for Sensing and Actuation

Fall and Spring: 3 units
Mechanical engineers design, build, and troubleshoot basic circuits that perform signal conditioning on sensor measurements and provide power amplification for actuation. This course covers the basics of passive circuit design, applications of operational amplifiers, and the use of transistors to amplify low power signals coming from microcontrollers. Lecture materials are coupled with hands-on in-class exercises and homework assignments using the Arduino to interface with sensors and actuators.
Prerequisite: 24-101

24-261 Mechanics I: 2D Design

Fall: 10 units
This is the first course in a three-semester sequence that integrates the principles of mechanics with hands-on projects that have students apply those principles in a design context. In the first semester, students review and extend methods of 2D statics to study single and multiple bodies, such as structures and machines. Internal loads in 2D are defined and quantified, followed by a study of stresses and strains under axial loading, bending and shear. Students will also learn engineering design process methods and skills, including concept design, detailed design, analysis, fabrication, and testing. As topics are introduced and applied by students in hands-on assignments, they will compare theoretical computations and experimental testing of their design ideas, so as to reinforce fundamentals and practice the engineering design process.
Prerequisites: 21-122 Min. grade C and (33-106 or 33-141 or 33-121 or 33-151) and 24-101

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-262 Mechanics II: 3D Design

Spring: 10 units
This is the second course in a three-semester sequence that integrates the principles of mechanics with hands-on projects that have students apply those principles in a design context. In the second semester, students extend their foundation in 2D statics to the analysis of 3D engineering systems, including determination of reactions at connections and internal loads. Friction, shear stress, and shear strain are introduced, followed by a study of stresses and deformation in torsion. Multiaxial stresses, such as those occurring in combinations of torsion and bending or in pressure vessels, are studied. Stress transformations are introduced, as well as the formulation of simple failure criteria. Students will expand their engineering design skills through team-based hands-on and computational projects that utilize stress and failure analysis of 3D engineered systems. In addition, students will learn elementary aspects of machine design and catalog selection to support projects. Altogether, students will learn to express ideas in sketches, interpret and create engineering drawings, model detailed shapes with CAD tools, analyze product performance with CAE tools, choose materials and manufacturing schemes, and create and test prototypes.
Prerequisites: (33-141 or 33-106 or 33-151) and 24-261

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-280 Special Topics: C++ Programming for Engineers

Fall and Spring: 9 units
Using the C++ programming language as a platform, this course serves as an intermediate-level programming course with a strong emphasis on software requirements for engineering applications. Students will refine and enhance their coding skills while applying their mathematical, analytical and design backgrounds. Topics covered include data structures, algorithm design, numerical computation, modular programming, data modeling, interactive graphics, object-orientation, and user interfaces, all in an engineering-specific domain.
Prerequisites: 15-110 or 15-112

Course Website: http://www.cmu.edu/me (http://www.cmu.edu/me/)

24-281 Introduction to Scientific Computing

Fall and Spring: 2 units
This course provides an introduction to scientific computing with Matlab for engineers. The course introduces the basics of Matlab syntax and programming, data analysis, visualization, curve fitting and interpolation, symbolic computation, differential equations, and debugging. The use of Matlab in solving mechanical engineering applications will be demonstrated.

Course Website: https://www.meche.engineering.cmu.edu/

24-291 Environmental Systems on a Changing Planet

Fall: 9 units
This course introduces the interconnected environmental systems that regulate our climate and ecosystems, providing the resources required to sustain all life, including human societies. These systems are the fascinating connections between the oceans, atmosphere, continents, ecosystems, and people that provide our planet with resources that all life depends on. Human activities disrupt these natural systems, posing critical threats to the sustainable functioning of environmental systems. We will explore how solar and biochemical energy moves through the Earths interconnected systems, recycling nutrients; how complex environmental systems function to produce critical resources such as food and water; and how human activities interfere with these systems. Earth science concepts will be used to explain the relationship between climate zones and biomes, the stability of the Earth's climate in the Holocene, and the instability in the current Anthropocene. Case studies include the interplay between climate change feedbacks, wildfires, ecosystems, and agricultural systems; the hazards that everyday chemical toxins pose to ecosystems and human health and reproduction; and growing threats to ecosystem health and biodiversity. We will also develop the relevant science and information literacy required to understand current issues that are frequently debated in the public sphere, and connect these to environmental justice.

24-292 Renewable Energy Engineering

Intermittent: 9 units
Introduction to engineering principles of various renewable energy systems, including the following topics: background on climate change and carbon sequestration, engineering analysis of renewable energy systems such as solar photovoltaic, (solar thermal), wind power, hydropower, wave energy, bio mass energy, geothermal energy, and hydrogen based fuel cells. In addition, transitional energy systems such as nuclear power and advanced combined cycles will be introduced. Both engineering performance and present state of development will be discussed. Students will review and present their progress on various subjects, which will be selected based on personal interest.
Prerequisites: 33-141 or 33-106

Course Website: http://www.andrew.cmu.edu/user/satbirs/24292/

24-300 TechSpark: CNC Machining

Fall and Spring: 2 units
This course builds upon previous skills taught in TechSpark's Manual Machining class. A significant portion of the course is dedicated to learning 2.5D Computer Aided Manufacturing (CAM) software, equipment setup, and machine operation. Homework assignments are important for reinforcement of skills learned, and the utilization of these skills will be applied to a self-directed project. This course is required to use the CNC milling machines in the student machine shop at TechSpark. 2-unit mini (7-weeks)
Prerequisite: 24-200

24-302 Professional Development for Mechanical Engineers

Fall and Spring: 2 units
This course prepares students to communicate verbally as an engineer. Students will practice and receive feedback on their oral communication in a range of contexts, including formal presentations, elevator pitches, job interview questions, and communicating technical concepts to non-engineers. In addition, students will be introduced to a range of professional topics, including ethical decision-making, communicating in global contexts, negotiation strategies, and strategies for overcoming implicit bias.
Student grades will be based upon weekly homework assignments, formal presentations, and class participation.

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-311 Numerical Methods

Spring: 10 units
Use of numerical methods for solving engineering problems with the aid of a digital computer. The course will contain numerical methods such as roots of equations, linear algebraic equations, optimization, curve fitting, integration, and differential equation solving. MATLAB will be used as the programming language. Programming cluster laboratory times will be available twice a week. Problems will be drawn from all fields of interest to mechanical engineers. 3 hrs. lecture plus lab
Prerequisites: 21-254 and 21-260

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-321 Thermal-Fluids Experimentation

Spring: 12 units
Thermal-Fluids Experimentation Spring: 12 units This is a capstone course for the thermal-fluids core-course sequence. This course covers techniques of measurement, uncertainty analysis, and realization of systems, which demonstrate fundamental principles in thermodynamics, fluid mechanics, and heat transfer. The principles of designing thermal experiments are also integrated into this course.
Prerequisites: 24-221 and 24-322 and 24-231

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-322 Heat Transfer

Fall: 10 units
Introduction to basic concepts of engineering heat transfer. Steady and transient heat conduction in solids, including the effect of heat generation. Finned surfaces. Correlation formulas for forced and free convection, condensation, and boiling. Design and analysis of heat exchangers. Radiation heat transfer. Problems in combined convection and radiation. Measurement techniques. 3 hrs. lec., 1 hr. recitation.
Prerequisites: 24-221 and 21-260 Min. grade C and 24-231

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-334 Introduction to Biomechanics

Fall: 9 units
This course covers the application of solid and fluid mechanics to living tissues. This includes the mechanical properties and behavior of individual cells, the heart, blood vessels, the lungs, bone, muscle and connective tissues as well as methods for the analysis of human motion.
Prerequisite: 24-231

Course Website: http://www.cmu.edu/me/

24-341 Manufacturing Sciences

Spring: 9 units
This course has two broad concerns: an introductory review of manufacturing systems organization and a review of common manufacturing processes from the point of view of design for manufacturability. The features of mass and batch production are quantitatively considered. The basic principles of group technology and production planning are outlined. The use of computers in manufacturing is described, together with a review of the current capabilities of industrial robots. Students will be involved in weekly seminars, which will describe the basic features of common manufacturing processes, including metal machining, metal forming, polymer processing, casting techniques, joining techniques, ceramic processing, and powder processing. Case studies from industry and films may be used. 3 hrs. rec.
Prerequisite: 24-262

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-351 Dynamics

Fall: 10 units
This first course on the modeling and analysis of dynamic systems concentrates on the motion of particles, systems of particles, and rigid bodies under the action of forces and moments. Topics include the kinematics of motion in rectangular, polar, and intrinsic coordinates; relative motion analysis with multiple reference frames; and planar kinetics through the second law, work-energy method, and impulse-momentum method. Time and frequency domain solutions to first and second order equations of motion are discussed. 3 hrs. lec. 1 hr rec.
Prerequisites: 24-101 and 21-260 Min. grade C

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-352 Dynamic Systems and Controls

Fall and Spring: 12 units
This second course on the modeling and analysis of dynamic systems emphasizes the common features, which are exhibited by physical systems that include mechanical, hydraulic, pneumatic, thermal, electrical, and electromechanical elements. State equations and the concepts of equilibrium, linearization, and stability are discussed. Time and frequency domain solutions are developed. 4 hr. lec.
Prerequisites: (33-107 and 21-260 Min. grade C and 24-251 and 24-351) or (24-351 and 33-142 and 24-251 and 21-260 Min. grade C) or (21-260 Min. grade C and 24-251 and 33-152) or (24-351 and 33-132 and 21-260 Min. grade C and 24-251)

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-354 Mechatronics Applications in Mechanical Engineering

Fall: 9 units
Most modern products contain elements of sensing, actuation, and control. This course builds on concepts from Dynamic Systems and Control to design simple mechatronic systems. Topics include modeling and selection of sensors and actuators, measurement systems, digital signal processing, microcontroller architectures, and the basics of state space control methods; these topics are taught in the context of integration with mechanical systems. This course includes a substantial project component in which students design, build, and test a mechatronic system through a series of subsystem prototypes and systems integration.
Prerequisite: 24-352

Course Website: http://www.cmu.edu/me/

24-358 Culinary Mechanics

Intermittent: 9 units
This course discusses how mechanical quantities and processes such as force, motion, and deformation influence food and the culinary arts. The aim of the course is to apply important aspects of mechanics to ideas in cooking. Specific topics include: (1) how do stress and strain affect food and its perceived taste; (2) what is the role of cell mechanics in the resulting micro structure of both consumed plant and animal tissues; (3) how can mechanics be used to alter nutrition; (4) what are the roles of common and uncommon mechanical tools such as a knife or mortar and pestle in food preparation. Emphasis will be placed on the biomechanics of edible matter across multiple length scales, including at the tissue, cellular, and molecular levels; additionally, impact on global health and engineering implications will be elucidated. During this course, we will introduce you to these concepts,train you to use them in real world applications, and allow you to pursue a creative group-defined project, which will be shared in both written and oral formats. We will integrate a hands-on kitchen experience in at least 3 specific laboratory classes so that students will get a true feel and understanding for culinary mechanics. We also will be visiting the restaurant of at least one first-rate Pittsburgh chef to gain real world insight into mechanics and cooking.

Course Website: http://www.cmu.edu/me/

24-370 Mechanical Design: Methods and Applications

Fall: 12 units
This is the third course in a three-semester sequence that integrates the principles of mechanics with hands-on projects that have students apply those principles in a design context. Building on the principles and design methodology introduced in the first two courses, this course consists of a detailed study of typical loading conditions and resulting stresses and deflections in commonly used machine elements, such as shafts, gears, power screws, fasteners, brakes/couplings, flywheels, and bearings, and best practices in their design and application. Machine design against static and dynamic failure will be considered with focus on the effect of material properties, manufacturability, and cost considerations. Students will also learn the connections between theory and analytical methods, available computational tools, and field design. Learning objectives will be assessed through homework, class exams, and the conduct of the group projects.
Prerequisites: 24-262 and 24-200

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-371 Special Topics: Design of Machine Elements

Spring: 9 units
In this class, the students will gain an understanding of the best practices in the design of machine elements such as shafts, gears, power screws, fasteners, brakes/couplings, flywheels, bearings, etc. The course material consists of the study of stress and deflection under common loading conditions, effect of material properties, static and fatigue failure models, cost considerations, and manufacturability in the context of the machine components. Student learning will be achieved through interactive lectures on underlying technical approaches in conjunction with a group project where students will be required to design and fabricate an ensemble of machine elements. Students will also learn about the strong connections between theory, analytical methods, available computational tools, and field design. Assessment of the learning objectives will happen via homework, class exams, and demonstration of the group project. This course builds upon the skills and methods taught in Design-I (24-370) and will help students prepare to enter the modern workplace where mechanical design takes place.
Prerequisite: 24-370

24-381 Environmental Systems on a Changing Planet

Fall: 12 units
This course introduces the interconnected environmental systems that regulate our climate and ecosystems, providing the resources required to sustain all life, including human societies. We will explore how solar and biochemical energy moves through the Earths interconnected systems, recycling nutrients; how complex environmental systems function to produce critical resources such as food and water; and how human activities interfere with these systems. Earth science concepts will be used to explain the relationship between climate zones and biomes, the stability of the Earth's climate in the Holocene, and the instability in the current Anthropocene. Case studies include the interplay between climate change feedbacks, wildfires, ecosystems, and agricultural systems; the hazards that everyday chemical toxins pose to ecosystems and human health and reproduction; and growing threats to ecosystem health and biodiversity. We will also develop the relevant science and information literacy required to understand current issues that are frequently debated in the public sphere, and connect these to environmental justice. This course draws on principles learned in high school science and serves as the foundational Earth and amp; Environmental Science requirement for both the Minor and Additional Major in Environmental and Sustainability Studies.

24-390 Mechanical Engineering Co-op

Fall and Spring
The Department of Mechanical Engineering at Carnegie Mellon considers practical learning opportunities important educational options for its undergraduate students. One such option is cooperative education, which provides a student with an extended work experience with a company or government institution. To participate, students must possess at least junior status and have an overall grade point average of 3.0 or above. Students must complete a Co-Op Approval Form and submit it for approval. If the application is approved, the course will be added to the student's schedule and the student will be assessed tuition for 0 units for each semester that the student participates. All co-ops must be approximately 5-8 months in uninterrupted length. Upon completion of the co-op experience, students must submit a 1-2 page report of their work experience, and a 1-2 page evaluation from the company supervisor to the ME Undergraduate Education Committee. If the reports are approved, a "P" grade will be assigned. International students should contact their academic advisor for additional information. Prerequisite: Special permission required

Course Website: https://www.meche.engineering.cmu.edu/education/undergraduate-education/index.html (https://www.meche.engineering.cmu.edu/education/undergraduate-education/)

24-391 Mechanical Engineering Project

Fall and Spring
Practice in the organization, planning, and execution of appropriate engineering projects. These investigations may be assigned on an individual or a team basis and in most cases will involve experimental work.

Course Website: https://www.meche.engineering.cmu.edu/education/undergraduate-education/index.html (https://www.meche.engineering.cmu.edu/education/undergraduate-education/)

24-392 Mechancial Engineering Project

All Semesters
Practice in the organization, planning, and execution of appropriate engineering projects. These investigations may be assigned on an individual or a team basis and in most cases will involve experimental work.

Course Website: https://www.meche.engineering.cmu.edu/education/undergraduate-education/index.html (https://www.meche.engineering.cmu.edu/education/undergraduate-education/)

24-421 Internal Combustion Engines

Fall: 12 units
This course discusses working principles of internal combustion engines found in many practical applications. Focus is given to understanding the design of air handing system, in-cylinder fuel/air mixing, geometric design of the combustion chamber, engine performance and calibration, and mechanism of pollutant formation and reduction. Introductory discussion of advanced automotive engine concepts, alternative fuels, gas turbine engines, rocket engines, and hybrid electric vehicles is also provided. The course relies on a number of lab experiments, analysis of actual experimental data, and a combination of analytical and numerical homework assignments. 3 hrs. lecture 2 hrs. lab
Prerequisites: 24-221 and 24-231

Course Website: http://www.andrew.cmu.edu/user/satbirs/24421/

24-424 Energy and the Environment

Fall: 9 units
Fuel cycles for conventional and non-conventional energy resources; relationships between environmental impacts and the conversion or utilization of energy; measures of system and process efficiency; detailed study and analysis of coal-based energy systems including conventional and advanced power generation, synthetic fuels production, and industrial processes; technological options for multi-media (air, water, land) pollution control; mathematical modeling of energy-environmental interactions and tradeoffs and their dependency on technical and policy parameters; methodologies for energy and environmental forecasting; applications to issues of current interest. Junior or Senior standing in CIT or permission of instructor. 3 hrs lecture

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-425 Combustion and Air Pollution Control

Intermittent: 9 units
Formation and control of gaseous and particulate air pollutants in combustion systems. Basic principles of combustion, including thermochemical equilibrium, flame temperature, chemical kinetics, hydrocarbon chemistry, and flame structure. Formation of gaseous and particulate pollutants in combustion systems. Combustion modifications and post-combustion technologies for pollutant control. Relationship between technology and regional, national, and global air pollution control strategies. The internal combustion engine and coal-fired utility boiler are used as examples. 3 hours lecture Cross listed as 24-740 and 19440/19-740

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-428 Computational Analysis of Transport Phenomena

Spring: 9 units
In this course, students will develop basic understanding and skill sets to perform simulations of transport phenomena (mass, momentum, and energy transport) for engineering applications using a CAE tool, learn to analyze and compare simulation results with theory or available data, and develop ability to relate numerical predictions to behavior of governing equations and the underlying physical system. First 8 weeks of the course will include lectures and simulation-based homework assignments. During last 7 weeks, teams of students will work on self-proposed projects related to computational analysis of transport phenomena. In the project, students will learn to approach loosely defined problems through design of adequate computational mesh, choice of appropriate numerical scheme and boundary conditions, selection of suitable physical models, efficient utilization of available computational resources etc. Each team will communicate results of their project through multiple oral presentations and a final written report. Detailed syllabus of the course is provided on the URL given below.
Prerequisites: 24-231 and 24-322 and 24-221

Course Website: http://www.andrew.cmu.edu/user/satbirs/24618/

24-441 Engineering Design II: Conceptualization and Realization

Fall and Spring: 12 units
This course guides students through the design process in the applied design of a practical mechanical system. Lectures describe the typical design process and its associated activities, emphasizing methods for innovation and tools for design analysis. Professional and ethical responsibilities of designers, interactions with clients and other professionals, regulatory aspects, and public responsibility are discussed. The design project is typically completed in teams and is based on a level of engineering knowledge expected of seniors. Proof of practicality is required in the form of descriptive documentation. Frequently, a working model will also be required. Oral progress reports and a final written and oral report are required. 3 hrs. rec., 3 hrs lab Senior standing and Machine Shop Practice 24-200 required.
Prerequisites: 24-370 and 24-302

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-451 Feedback Control Systems

Fall: 12 units
Fundamentals of feedback control with emphasis on classical techniques and an introduction to discrete-time (computer controlled) systems. Topics include the following: frequency domain modeling and state space modeling of dynamical systems; feedback control system concepts and components; control system performance specifications such as stability, transient response, and steady state error; analytical and graphical methods for analysis and design - root locus, Bode plot, Nyquist criterion; design and implementation of proportional, proportional-derivative, proportional-integral-derivative, lead, lag, and lead-lag controllers. Extensive use of computer aided analysis and design software. 4 hrs lec.
Prerequisites: (15-112 or 15-110) and 24-352

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-452 Mechanical Systems Experimentation

Fall and Spring: 9 units
Experimentation in dynamic systems and controls. The course will cover translational and rotational systems. Topics will include mechanical elements, natural frequencies, mode shapes, free and forced response, frequency response and Bode plots, time constants, transient response specifications, feedback controls such as PID control, and stability for single-degree-of-freedom and multi-degree-freedom systems. The course will introduce and use state-of-the-art experimentation hardware and software.
Prerequisite: 24-352

Course Website: http://www.cmu.edu/me/undergraduate/index.html (http://www.cmu.edu/me/undergraduate/)

24-453 Special Topics: Introduction to Programmable Logic Controllers

Fall and Spring: 3 units
Programmable Logic Controllers (PLCs) are prevalent in many industrial process control and manufacturing applications. Knowledge of and experience with PLCs is a marketable skill, opening up many career opportunities in a wide range of industries. This course provides an introduction to the applications of PLCs and techniques used for their programming and implementation. The course will be primarily lab-based, aimed at introducing the capabilities, limitations, and applications of PLCs through hands-on experience. Topics include ladder logic, PLC programming, PLC memory structures, program execution, troubleshooting methods, and typical industrial practices.
Prerequisite: 24-352

24-480 Special Topics: Artificial Intelligence and Machine Learning for Engineering

Spring: 9 units
This course introduces algorithms that are at the center of modern day artificial intelligence (AI) and machine learning (ML) techniques. The course takes an engineering-focused approach to AIML by investigating the wide array of sources of data available in the world, how these sources generate data, and algorithms and methods that are used to transform this data into knowledge/insights.
Prerequisites: (15-112 or 15-110) and (36-220 or 19-250 or 36-225 or 36-217)

24-491 Department Research Honors

Fall and Spring
This course is designed to give students increased exposure to "open-ended" problems and research type projects. It involves doing a project on a research or design topic and writing a thesis describing that project. The project would be conducted under the supervision of a mechanical engineering faculty member (the advisor), and must be approved by the advisor before inception. This course can be taken at any time after the Junior year and before graduation which includes the summer after the Junior year. Completion of 18 units of this course with a grade of B or better is a partial fulfillment of the requirements for Departmental Research Honors.

Course Website: https://www.meche.engineering.cmu.edu/education/undergraduate-education/index.html (https://www.meche.engineering.cmu.edu/education/undergraduate-education/)

24-492 Department Research Honors

Fall and Spring
This course is designed to give students increased exposure to "open-ended" problems and research type projects. It involves doing a project on a research or design topic and writing a thesis describing that project. The project would be conducted under the supervision of a mechanical engineering faculty member (the advisor), and must be approved by the advisor before inception. This course can be taken at any time after the Junior year and before graduation which includes the summer after the Junior year. Completion of 18 units of this course with a grade of B or better is a partial fulfillment of the requirements for Departmental Research Honors.

Course Website: https://www.meche.engineering.cmu.edu/education/undergraduate-education/index.html (https://www.meche.engineering.cmu.edu/education/undergraduate-education/)

24-602 Maker Series: Prototyping for Equity

Spring
This course applies prototyping techniques to develop products for underserved populations of people. In order to fabricate components for prototypes, this course teaches the safe operation of fabrication tools, including 3D printer, laser cutter-engraver machine, and power tools. A significant portion of the course is dedicated to applying the engineering design cycle to meet the unique needs/wants of a specific user population. This hands-on course culminates in building a prototype that can be tested to validate its performance as the physical solution to a real-world problem. 5-6-unit mini (7-weeks)

24-614 Microelectromechanical Systems

Intermittent: 12 units
This course introduces fabrication and design fundamentals for Microelectromechanical Systems (MEMS): on-chip sensor and actuator systems having micron-scale dimensions. Basic principles covered include microstructure fabrication, mechanics of silicon and thin-film materials, electrostatic force, capacitive motion detection, fluidic damping, piezoelectricity, piezoresistivity, and thermal micromechanics. Applications covered include pressure sensors, micromirror displays, accelerometers, and gas microsensors. Grades are based on exams and homework assignments.
Prerequisites: 24-351 or 18-321

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-623 Molecular Simulation of Materials

Spring: 12 units
The purpose of this course is to expose engineering students to the theory and implementation of numerical techniques for modeling atomic-level behavior. The main focus is on molecular dynamics and Monte Carlo simulations. Students will write their own simulation computer codes, and learn how to perform calculations in different thermodynamic ensembles. Consideration will be given to heat transfer, mass transfer, fluid mechanics, mechanics, and materials science applications. The course assumes some knowledge of thermodynamics and computer programming. 4 hrs lec.
Prerequisites: 24-221 and 24-311

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-626 Air Quality Engineering

Fall: 12 units
The course provides a quantitative introduction to the processes that control atmospheric pollutants and the use of mass balance models to predict pollutant concentrations. We survey major processes including emission rates, atmospheric dispersion, chemistry, and deposition. The course includes discussion of basic atmospheric science and meteorology to support understanding air pollution behavior. Concepts in this area include vertical structure of the atmosphere, atmospheric general circulation, atmospheric stability, and boundary layer turbulence. The course also discusses briefly the negative impacts of air pollution on society and the regulatory framework for controlling pollution in the United States. The principles taught are applicable to a wide variety of air pollutants but special focus is given to tropospheric ozone and particulate matter. The course is intended for graduate students as well as advanced undergraduates. It assumes a knowledge of mass balances, fluid mechanics, chemistry, and statistics typical of an undergraduate engineer but is open to students from other scientific disciplines.
Prerequisites: 09-105 and 36-220 and 24-231

Course Website: http://www.cmu.edu/me/

24-628 Energy Transport and Conversion at the Nanoscale

Spring: 12 units
Energy transport and conversion processes occur at the nanoscale due to interactions between molecules, electrons, phonons, and photons. Understanding these processes is critical to the design of heat transfer equipment, thermoelectric materials, electronics, light emitting diodes, and photovoltaics. The objective of this course is to describe the science that underlies these processes and to introduce the contemporary experimental and theoretical tools used to understand them. The course includes a laboratory that gives the students experience with modern transport measurement instrumentation and data analysis. Integrated literature reviews and a final project require students to apply learned fundamentals to understand state-of-the-art research and technology. 4 hrs. lecture
Prerequisites- 24-322 and amp; 24-221 or equivalents
Prerequisites: 24-221 and 24-322

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-629 Direct Solar and Thermal Energy Conversion

Intermittent: 12 units
This course introduces graduates and senior undergraduates the principles and technologies for directly converting heat and solar light into electricity using solid-state devices. The first part of the course reviews the fundamentals of quantum mechanics, solid state physics and semiconductor device physics for understanding solid-state energy conversion. The second part discusses the underlying principles of thermoelectric energy conversion, thermionic energy conversion, and photovoltaics. Various solar thermal technologies will be reviewed, followed by an introduction to the principles of solar thermophotovoltaics and solar thermoelectrics. Spectral control techniques which are critical for solar thermal systems will also be discussed. By applying the basic energy conversion theory and principles covered in lectures, students will finish a set of 4 homework assignments. This course also requires one project in which students will work individually to review one present solar or thermal energy conversion technology 12 units

Course Website: http://www.cmu.edu/me/

24-631 Thermal Design

Spring: 12 units
This course guides students through the design process of a practical thermal system. The course plan assumes a mastery of the fundamentals of thermodynamics, fluid mechanics and heat transfer at the undergraduate level. Lectures aim at design aspects and analysis techniques commonly used in the development of thermal systems. Lecture topics include heat sinks, heat pipes, compact heat exchangers, sensors and instrumentation, thermoelectric devices, and special topics closely related to the theme of the design activity for the semester. Design activity is conducted in teams and includes several cycles of oral presentations, class discussions, and a final written report. System design and analysis of performance are heavily based on computer-added design tools and simulation means. Student performance in this course is evaluated based on individual homework assignments on the various topics presented in class and on a team design project.
Prerequisites: 24-370 and 24-302 and 24-322

24-632 Special Topics: Additive Manufacturing Processing and Product Development

Fall: 12 units
Introduction to additive manufacturing (AM) processing fundamentals and applications using Solidworks 3-D CAD software and a variety of polymer and metal AM machines. Includes a brief history of AM processing, a review of and technical fundamentals of current AM processes, a study of the current AM market, and future directions of the technology. Lab Sessions will support an open-ended product development project. Lectures on metals AM will address current research impacting industry. Students will also perform a literature review of papers on the state of the art. Basic Solidworks knowledge required.

Course Website: http://www.cmu.edu/me/

24-633 Additive Manufacturing Laboratory

Spring: 12 units
Hands-on laboratory projects will teach students about all aspects of metals additive manufacturing (AM). Students will learn how to use SOLIDWORKS for part design, create and transfer design files to the AM machines, run the machines to build parts, perform post-processing operations, and characterize AM parts. Students will work in teams and complete three separate lab projects, each utilizing a different material system, part design, AM process/machine, post-processing steps and characterization methods. A major lab report and presentation will be required for each of the three lab projects. The course includes weekly lectures to complement the laboratory component. Priority for enrollment will be given to students who have declared the Additive Manufacturing Minor.
Prerequisites: 24-632 or 39-602 or 27-503 or 27-765 or 39-601

24-634 Structural Design

Spring: 12 units
Design of structural members for bending moment, shear force, axial force, and combined axial force and bending. Reinforced concrete, structural steel, and composite beam construction are considered. Buckling effects in columns, beams and local plate segments are treated. Serviceability limits such as deflection and cracking are addressed. Design projects include the determination of loads and the selection of system geometry.
Prerequisite: 24-262

24-635 Structural Analysis

Fall: 12 units
Classical and matrix-based methods of structural analysis; energy principles in structural mechanics. Basic concepts of force and displacement methods for analyzing redundant structural systems. Matrix methods utilizing the flexibility (force) and stiffness (displacement) concepts.
Prerequisite: 24-262

24-636 Energy Applications in Biology and Medicine

Spring: 12 units
This course covers a wide range of energy-based applications in biology and medicine, such as cancer treatments by cryosurgery (freezing), thermal ablation (heating), photodynamic therapy (light-activated drugs), and irreversible electroporation (a non-thermal electrical application). This course also covers thermal regulation in humans and other mammals, as well as cryopreservation (low-temperature preservation) of tissues and organs for the benefit of organ banking and transplant medicine. The course combines lectures and individual assignments relating to the underlying principles of engineering, with teamwork on open-ended projects relating to concurrent challenges at the convergence of engineering and medical sciences. The course plan assumes a mastery of the fundamentals of heat transfer at the undergraduate level
Prerequisite: 24-322

24-637 Manufacturing Futures

Spring: 12 units
The course will introduce an array of technologies that will contribute to the future of making things and will be organized into 4 logical modules that will culminate in a team-based design project. Module 1 (Manufacturing Visions and Design Methodolgy): David Bourne. Module 2 (Manufacturing Processes and Process Tradeoffs): Brandon Bodily. Module 3 (Electronic Manufacturing): Rahul Panat. Module 4 (Workforce Development) : David Bourne.

24-640 Climate Change Mitigation

Intermittent: 12 units
Have you ever thought about how we could address the climate change problem? In this course we will study the technological and policy options for responding to the threat of climate change. We will review climate-change science, understand the current systems for energy supply and use, and have a deep dive onto technological solution for low-carbon energy supply and use, as well as the policy frameworks that can help us reduce greenhouse gas emissions. 2hrs 40min of lectures per week.

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-643 Energy Storage Materials and Systems

Intermittent: 12 units
Contemporary energy needs require large scale electrochemical energy conversion and storage systems. Batteries are playing a prominent role in portable electronics and electric vehicles. This course introduces principles and mathematical models of electrochemical energy conversion and storage. Students will study thermodynamics, reaction kinetics pertaining to electrochemical reactions, phase transformations relating to batteries. This course includes applications to batteries, fuel cells, supercapacitors

Course Website: http://www.andrew.cmu.edu/user/venkatv/24643/

24-650 Applied Finite Element Analysis

Intermittent: 12 units
This is an introductory course on the finite element method with emphasis on application of the method to a wide variety of problems. The theory of finite element analysis is presented and students learn various applications of the method through assignments utilizing standard finite element software packages commonly used in industry. Various types of analyses are considered, which may include, for example, static, pseudo-static, dynamic, modal, buckling, contact, heat transfer, thermal stress and thermal shock. Students also learn to use a variety of element types in the models created, such as truss, beam, spring, solid, plate, and shell elements.
Prerequisites: 24-322 and 24-262

Course Website: https://www.meche.engineering.cmu.edu/education/graduate-programs/index.html (https://www.meche.engineering.cmu.edu/education/graduate-programs/)

24-651 Material Selection for Mechanical Engineers

Spring: 12 units
This course provides a methodology for selecting materials for a given application. It aims to provide an overview of the different classes of materials (metal, ceramic, glass, polymer, elastomer or hybrid) and their properties including modulus, strength, ductility, toughness, thermal conductivity, and resistance to corrosion in various environments. Students will also learn how materials are processed and shaped (e.g., injection molding, casting, forging, extrusion, etc.), and will explore the origins of the properties, which vary by orders of magnitude. Topics include: Materials selection by stiffness, strength, fracture toughness and fatigue. Shape factors and materials processing. Binary phase and time temperature transformation diagrams, microstructure. Polymer types and structures. Alloying and strengthening of metals, types of steels. Corrosion, oxidation, tribology and thermal properties.
Prerequisites: 09-105 and 24-262

Course Website: http://www.cmu.edu/me/

24-652 Mechanical Behavior of Engineering Materials

Intermittent: 12 units
Mechanical engineers employ all classes of materials (metals, polymers, ceramics and hybrids) in load-bearing applications. To reduce material cost, save energy and maximize performance, engineering materials are frequently designed to be used near their load-bearing limits. An understanding of underlying deformation mechanisms complements a design rule approach in that "unexpected" failures can be far better anticipated and hence minimized. This course will survey the major deformation mechanisms in the main materials classes. Topics will include structure, elasticity, continuum failure models, fracture mechanics, and plastic deformation mechanisms of polymers, fiber-reinforced, composites, ceramics and metals. Proper design practice and real-life failures will be discussed.
Prerequisite: 24-262

Course Website: http://www.cmu.edu/me/

24-653 Special Topics: Materials and Their Processing for Mechanical Engineers

Spring: 12 units
The study of the major classes of materials (e.g., metals, alloys, ceramics, polymers, composites) and their structure-processing-property relationships is integral to many engineering disciplines. This course will introduce the fundamental concepts behind how the processing of materials influences their atomic/molecular structures and resulting properties. The course will adopt a game-based learning approach in which students will utilize the virtual Minecraft environment to study crystal structures, imperfections (defects), diffusion, and phase equilibria. These concepts are then applied to characterize and interpret the (mechanical, electrical, magnetic, and optical) properties of various material systems as part of a final collaborative group project.

24-654 Special Topics: Welding Engineering

Spring: 12 units
This course introduces the Welding Engineering field by teaching its fundamental aspects (e.g. metallurgy, solidification, heat transfer, arc physics, etc.) as applied to welding common ferrous and non ferrous materials with representative fusion (e.g. GMAW, LBW) and solid-state (e.g. FSW, FW) based processes and aspects of their use in production (i.e. variables to control, specific techniques and methodologies, standards/specifications, inspection and amp; testing of welds to ensure their quality). This will provide students with the knowledge to start to become more conversant in this discipline and to those that elect to further delve and specialize in specific areas of joining and amp; assembly, the preparation/step-stone to start to do so in their careers in industry or academia.

24-655 Cellular Biomechanics

Intermittent: 9 units
This course discusses how mechanical quantities and processes such as force, motion, and deformation influence cell behavior and function, with a focus on the connection between mechanics and biochemistry. Specific topics include: (1) the role of stresses in the cytoskeleton dynamics as related to cell growth, spreading, motility, and adhesion; (2) the generation of force and motion by moot molecules; (3) stretch-activated ion channels; (4) protein and DNA deformation; (5) mechanochemical coupling in signal transduction. If time permits, we will also cover protein trafficking and secretion and the effects of mechanical forces on gene expression. Emphasis is placed on the biomechanics issues at the cellular and molecular levels; their clinical and engineering implications are elucidated. 3 hrs. lec.
Prerequisite: Instructor permission.

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-656 Introduction to Vibrations with Applications

Spring: 12 units
This is an introductory course in vibrations and structural dynamics. Vibrations are frequently observed in mechanical (e.g., automobiles, robots), aerospace (e.g., airplanes, satellites), civil (e.g., buildings, bridges), and biological (e.g., eardrum, myocardial cells) systems. As such, modeling, analysis, experimentation, and control of vibrations are critical for many systems. This course covers fundamental concepts on vibrations of simplified (single- and multi-degree-of-freedom lumped-parameter models) and distributed-parameter systems (strings, beams in bending and torsion). Various applications of vibrations are analyzed. An overview of vibration testing and experimental modal analysis is also provided. The topics include free and forced response of single- and multi-degree of freedom structures; harmonic response analysis; vibration suppression; Lagrange's equations to derive the equations of motion; vibrations of strings and beams; and numerical methods to determine natural frequencies and mode shapes.
Prerequisites: 24-352 and 24-351

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-658 Image-Based Computational Modeling and Analysis

Spring: 12 units
Image-based computational modeling and analysis play an important role in mathematical modeling and computer simulation of many physical and biological phenomena. This course integrates mechanical engineering, biomedical engineering, material sciences, computer science, and mathematics together. Topics to be studied include scanning techniques, image processing, geometric modeling, mesh generation, computational mechanics, as well as broad applications in biomedicine, material sciences and engineering. The techniques introduced are applied to examples of multi-scale modeling and simulations in various research fields.

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-663 Special Topics: Biomechanics of Human Movement

Spring: 12 units
This course provides an overview of the mechanical principles underlying human movement biomechanics and the experimental and modeling techniques used to study it. Specific topics will include locomotion, motion capture systems, force plates, muscle mechanics, musculoskeletal modeling, three dimensional kinematics, inverse dynamics, forward dynamic simulations, and imaging-based biomechanics. Homework and final class projects will emphasize applications of movement biomechanics in orthopedics, rehabilitation, and sports. ***Students are expected to have knowledge of ordinary differential equations and rigid body dynamics at the level of 24-351.***

24-664 Introduction to Biomechanics

Fall: 12 units
The purpose of this course is to achieve a broad overview of the application of mechanics to the human body. This includes solid, fluid, and viscoelastic mechanics applied to single cells, the cardiovascular system, lungs, muscles, bones, and human movement. The physiology of each system will be reviewed as background prior to discussing mechanics applications within that system. There are no firm prerequisites, but statics, fluid mechanics, and biology are helpful.

Course Website: http://www.cmu.edu/me/

24-665 Special Topics: Wearable Health Technologies

Spring: 12 units
This project-based course will provide an overview of emerging wearable health technologies and give students hands-on experience in solving ongoing technical challenges. The wearable sensing field is experiencing explosive growth, with exciting applications in medicine. New lightweight devices will make it easier to monitor health conditions in real time, automatically import data into health informatics systems, and provide haptic feedback with humans in the loop. We will review several aspects of these technologies, including hardware, software and big data analytics, user experience, and applications. Students will be working collaboratively in a semester-long project that tackles timely experimental and computational challenges. Programing experience, in any language, is a pre-requisite.

Course Website: https://www.meche.engineering.cmu.edu/education/courses/24-665.html

24-666 Special Topics: Introduction to Geometric Dimensioning and Tolerancing

Spring: 3 units
Geometric Dimensioning and Tolerancing (GD and amp;T) encompasses a language and system of rules used to precisely and unambiguously communicate the intended geometry and allowable variation of manufactured objects. This tolerance informs the design, process selection, tooling, and inspection of a part. This course will introduce students to this system of communication and its applications. Topics will include interpreting GD and amp;T on engineering drawings, implementing it in Solidworks, and performing tolerance analyses.
Prerequisite: 24-370

24-667 Special Topics: Introduction to Geometric Dimensioning and Tolerancing

Spring: 6 units
Geometric Dimensioning and Tolerancing (GD and amp;T) encompasses a language and system of rules used to precisely and unambiguously communicate the intended geometry and allowable variation of manufactured objects. This tolerance informs the design, process selection, tooling, and inspection of a part. This course will introduce students to this system of communication and its applications. Topics will include interpreting GD and amp;T on engineering drawings, implementing it in Solidworks, and performing tolerance analyses.

24-668 Mechatronics Applications in Mechanical Engineering

Fall: 12 units
Most modern products contain elements of sensing, actuation, and control. This course builds on concepts from Dynamic Systems and Control to design simple mechatronic systems. Topics include modeling and selection of sensors and actuators, measurement systems, digital signal processing, microcontroller architectures, and the basics of state space control methods; these topics are taught in the context of integration with mechanical systems. This course includes a substantial project component in which students design, build, and test a mechatronic system through a series of subsystem prototypes and systems integration.

24-671 Electromechanical Systems Design

Fall: 12 units
This course guides students through the design process as applied to mechatronic systems, which feature electrical, mechanical, and computational components. Lectures describe the typical design process and its associated activities, emphasizing methods for analyzing and prototyping mechatronic systems. Professional and ethical responsibilities of designers, interactions with clients and other professionals, regulatory aspects, and public responsibility are discussed. The design project is team-based and is based on a level of engineering knowledge expected of seniors. Proof of practicality is required in the form of descriptive documentation and a working prototype system at the end of the course. Oral progress reports and a final written and oral report are required.
Prerequisites: 24-370 and 24-302 and 24-352

Course Website: http://www.cmu.edu/me/

24-672 Special Topics in DIY Design and Fabrication

Fall: 12 units
The traditional principles of mass production are being challenged by concepts of highly customized and personalized goods. A growing number of do-it-yourself (DIY) inventors, designers, makers, and entrepreneurs is accelerating this trend. This class offers students hands-on experience in DIY product design and fabrication processes. Over the course of the semester, students work individually or in small groups to design customized and personalized products of their own and build them using various DIY fabrication methods, including 3D laser scanning, 3D printing, laser cutting, molding, vacuum forming, etc. In addition to design and fabrication skills, the course teaches students skills for communicating their ideas effectively through industrial design sketches and presenting their products with aesthetically refined graphics.

Course Website: https://www.andrew.cmu.edu/course/24-672/

24-673 Soft Robots: Mechanics, Design and Modeling

Spring: 12 units
Soft, elastically-deformable machines and electronics will dramatically improve the functionality, versatility, and biological compatibility of future robotic systems. In contrast to conventional robots and machines, these ? soft robots? will be composed of elastomers, gels, fluids, gas, and other non-rigid matter. We will explore emerging paradigms in soft robotics and study their design principles using classical theories in solid mechanics, thermodynamics, and electrostatics. Specific topics include artificial muscles, peristaltic robotics, soft pneumatic robotics, fluid-embedded elastomers, and particle jamming. This course will include a final project in which students may work individually or as a team. For the project, students are expected to design and simulate and/or build all or part (eg. sensors, actuators, grippers, etc.) of a soft robot. Prerequisites: Statics and Stress Analysis or equivalents.
Prerequisite: 24-262

Course Website: http://www.cmu.edu/me/

24-677 Modern Control Theory

Fall: 12 units
This course offers a practical introduction to the analysis and design of model-based control for linear systems. Topics include modeling and linearization of multi-input multi-output dynamic systems using the state-variable description, fundamentals of linear algebra (linear space, linear transformation, linear dynamics), analytical and numerical solutions of systems of linear time-invariant differential and difference equations, structural properties of linear dynamic physical systems (controllability, observability and stability), canonical realizations, and design of state feedforward/feedback, optimal, and stochastic controllers and observers (pole placement, LQR, MPC, Kalman filter approaches). Students will learn how to design linear controllers and implement them to solve real-world problems in control and robotics.

Course Website: https://www.meche.engineering.cmu.edu/education/graduate-programs/index.html (https://www.meche.engineering.cmu.edu/education/graduate-programs/)

24-680 Quantitative Entrepreneurship: Analysis for New Technology Commercialization

Intermittent: 12 units
This course provides engineers with a multidisciplinary mathematical foundation for integrated modeling of engineering design and enterprise planning decisions in an uncertain, competitive market. Topics include economics in product design, manufacturing and operations modeling and accounting, consumer choice modeling, survey design, conjoint analysis, decision-tree analysis, optimization, model integration and interpretation, and professional communication skills. Students will apply theory and methods to a team project for a new product or emerging technology, developing a business plan to defend technical and economic competitiveness. This course assumes fluency with basic calculus, linear algebra, and probability theory.

24-681 Computer-Aided Design

Intermittent: 12 units
his course is the first section of the two-semester sequence on computational engineering. Students will learn how computation and information technologies are rapidly changing the way engineering design is practiced in industry. The course covers the theories and applications of the measurement, representation, modeling, and simulation of three-dimensional geometric data used in the engineering designed process. Students taking this course are assumed to have knowledge of the first course in computer programming. 4 hrs lecture, 2 hrs computer cluster

Course Website: http://www.andrew.cmu.edu/course/24-681/

24-683 Design for Manufacture and the Environment

Fall: 12 units
Design for Manufacturing and the Environment examines influences of manufacturing and other traditionally downstream issues on the overall design process. Manufacturing is one facet that will be examined. Other downstream influences that will be studied include: assembly, robustness and quality, platform design, maintenance and safety, economics and costing, lean manufacturing and globalization. In addition, a core part of the course will focus on environment-based design issues. The class will study basic fundamentals in each of these areas and how they affect design decisions. Prerequisites: Senior standing in mechanical engineering, or permission of instructor

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-684 Special Topics: Nanoscale Manufacturing Using Structural DNA Nanotechnology

Fall: 12 units
This course provides an introduction to modern nanoscale manufacturing using structural DNAnanotechnology. This DNA-based approach to manufacturing has much in common with other fabrication methods in micro- and nano-engineering: computer aided design tools are necessary for device design and resulting structures can only be seen using advanced microscopy. However, instead of machining larger materials down to micro- and nanostructures, DNA origami is fabricated using a "bottom up" approach for self-assembling individual oligonucleotides into 2D and 3D nanostructures. Resulting structures can be designed to have novel mechanical and electrical properties and have applications as broad-ranging as medicine, biological computing, and energy systems. The course will include lectures, hands-on physical modeling, homework problems, 3D modeling of DNA origami using caDNAno and CANDO software, and student team projects and presentations.

Course Website: https://www.meche.engineering.cmu.edu/

24-685 Engineering Optimization without Project

Fall: 9 units
This course introduces students to 1) the process of formally representing an engineering design or decision-making problem as a mathematical problem and 2) the theory and numerical methods needed to understand and solve the mathematical problem. Theoretical topics focus on constrained nonlinear programming, including necessary and sufficient conditions for local and global optimality and numerical methods for solving nonlinear optimization problems. Additional topics such as linear programming, mixed integer programming, global optimization, and stochastic methods are briefly introduced. Model construction and interpretation are explored with metamodeling and model reformulation techniques, study of model boundedness, constraint activity, and sensitivity analysis. Matlab is used in homework assignments for visualization and algorithm development, and students apply theory and methods to a topic of interest in a course project. Fluency with multivariable calculus, linear algebra, and computer programming is expected. Students who are unfamiliar with Matlab are expected to learn independently using available tutorials and examples provided. This course is identical to 24-785 Engineering Optimization, except students in 24-685 will not complete the project, but will be responsible for any homework assignments and exams. 19785 and 24785: 12-units including the team-based engineering optimization project 19685 and 24685: 9-units excluding the project
Prerequisites: 21-341 and 21-259

Course Website: http://www.cmu.edu/me/

24-686 Advanced Mechanical Design

Intermittent: 12 units
This course will build expert foundational knowledge in mechanical design. Students will perform a series of multi-week modules in which they design, fabricate, and test high-performance mechanical components or assemblies individually or in small teams. Interactive lectures and topic readings on underlying technical approaches will occur simultaneously, thereby drawing a strong connection between theory, analytical methods, computational tools, and experience-based intuition. Modules will address optimal structures for tensile, bending, buckling, and torsion conditions, fatigue life, mechanism design, fluid power system design, and optimization of dynamical system properties. This course builds on the skills and methods taught in 24-370, Engineering Design I, and students are recommended to first take 24-370 and its prerequisites or similar courses at their undergraduate institution. Priority will be given to students who have already passed 24-200 Machine Shop Practice.
Prerequisite: 24-370

Course Website: http://www.cmu.edu/me (http://www.cmu.edu/me/)

24-687 Special Topics: New Technology Development and Roadmapping

Fall: 12 units
This course teaches a set of quantitative analysis methods fundamental to technology development and assessing the potential of emerging technologies. Students apply the analysis methods to a particular technology of their choosing in a project. The analysis tools learned in the course allow students to identify critical factors for advancing emerging technologies, strategizing R and amp;D to meet technical and market adoption targets, and predicting future technology performance. Topics include production models, adoption S-curves, dynamic consumer preferences, materials selection, and valuation of technological breakthroughs. Assignments include a series of presentations and written reports. The course assumes familiarity with college-level introductory probability and statistics.

Course Website: http://www.cmu.edu/me/

24-688 Introduction to CAD and CAE Tools

Fall: 12 units
This course offers the hands-on training on how to apply modern CAD and CAE software tools to engineering design, analysis and manufacturing. In the first section, students will learn through 7 hands-on projects how to model complex free-form 3D objects using commercial CAD tools. In the second section, students will learn through 7 hands-on projects how to simulate complex multi-physics phenomena using commercial CAE tools. Units: 12 Format: 2 hrs. Lec., 2 hrs. computer lab
Prerequisites: 24-262 and 24-231

Course Website: http://www.cmu.edu/me/

24-691 Mechanical Engineering Project Management

Fall and Spring: 12 units
Organizations are increasingly adopting formal project management techniques to successfully initiate, plan, execute, monitor, control, and close out projects. In this course, students will learn project management tools which are commonly applied in industry. Working in teams, students will incorporate these tools into a documented plan for a project on which they are currently working or have previously completed. The project plan will address the ten knowledge areas of project management, including the management of project integration, scope, schedule, cost, quality, resources, communications, risk, procurement, and stakeholders. Students will also work in teams to plan and manage simulated projects. Real world constraints, challenges, and incentives will be applied. Additional special topics in project management will be discussed based on student interest, which may include lean, iterative, incremental, and industry-specific approaches, as well as productivity and human relations principles, and project management professional certification.

Course Website: http://www.cmu.edu/me/

24-692 Special Topics: Engineering a Startup: How to Start and Grow a Hardware Company

Fall: 12 units
Many modern devices are created by entrepreneurs starting their own enterprises. This course will provide a practical foundation for creating a new technology company. Specifically, it focuses on the unique challenges with creating, funding, and scaling a hardware-centric startup, with a heavy focus on examining real world examples of engineered product companies. Topics will include: issues with product development processes in a startup setting, identifying key market differentiators, launching a product to market, fund raising strategies, establishing and scaling manufacturing, and creating and understanding financial statements. This class is geared towards students with no business experience. The class will feature guest speakers with entrepreneurial experience developing and launching high tech products. The class will culminate with student teams creating and presenting an original pitch deck to a review board of entrepreneurs and investors.

Course Website: http://www.cmu.edu/me/

24-693 Special Topics: Leadership and Communication

Fall and Spring: 12 units
The objective of this course is to prepare students to be better leaders and communicators in their future careers, in industry, academia, and elsewhere. Topics include: psychological analysis of leaders and followers, negotiation and conflict resolution, interviewing, organizational decision making, and harnessing and deploying skills in challenging situations. To address these topics, the course employs new teaching techniques involving hands on activities, for example mock interviews and role playing around challenging situations. Learning outcomes include: improved ability to adapt, communicate, and lead in difficult situations in real time, understand team interactions and group dynamics to become a successful leader and follower, best practices in negotiating and resolving conflict in team situations and business interactions, and understand fundamentals of the interview process to achieve best outcomes.

24-695 Academic and Professional Development for Mechanical Engineering Masters Student

Fall: 1 unit
This course, required for all first-year masters students in the Department of Mechanical Engineering, will cover fundamental and practical topics for their academic and professional development. The course offers ten one-hour workshop sessions throughout the fall semester. A short assignment will be given after each session. The sessions will cover three categories of topics: (1) career planning, (2) graduate study, and (3) social issues. The first category covers alumni panels, Ph.D. panels, and employer information. The second category covers time management and group dynamics. The third category covers diversity, equity and inclusion, ethics, and academic integrity. Assessment Structure: Attendance and assignments

24-696 Professional Communication in Engineering

Fall and Spring: 5 units
This course, required for all masters students in the Department of Mechanical Engineering, will help students hone their written and oral communication skills for the workplace. Students will meet weekly throughout a semester to learn communication strategies, practice those strategies in formal and informal contexts, and give and receive peer feedback. There will be weekly deliverables (both written and oral) that will receive formal feedback from communication TAs. To maximize learning benefits, students will have the option to revise assignments in order to improve their skills. Topics covered include: preparing brief (30-60 second) pitches, responding to job interview questions, writing challenging emails, writing progress reports, writing executive summaries, presenting technical work to non-experts, writing project descriptions for non-experts, creating a web portfolio.

24-697 Research Communication in Mechanical Engineering

Spring: 4 units
This course, required for all MSME-R students, will support students in effectively writing and presenting their final research projects. Students will meet bi-weekly throughout a semester to learn communication strategies and give and receive peer feedback. There will be weekly deliverables (both written and oral) that will receive formal feedback from communication TAs. Topics covered include: writing a proposal, describing your project for different audiences, data visualization, designing a research poster, orally presenting your project in different venues, responding to questions about your project.

24-703 Numerical Methods in Engineering

Fall: 12 units
This course covers numerical methods for solving a range of mathematical problems that are encountered in the analysis of engineering applications. Procedures will be presented for solving problems related to systems of equations, regression, optimization, integration, eigenvalues, ordinary differential equations, and partial differential equations. Students will be required to develop and implement computer algorithms and then apply them to engineering systems. Some programming experience is required.

Course Website: http://www.cmu.edu/me/graduate/courses.html

24-704 Probability and Estimation Methods for Engineering Systems

Fall: 12 units
Overview of rules of probability, random variables, probability distribution functions, and random processes. Techniques for estimating the parameters of probability models and related statistical inference. Application to the analysis and design of engineered systems under conditions of variability and uncertainty. 12 units Prerequisites(s) 26-211, or 36-220 or equivalent. Cross listed CEE 12-704
Prerequisite: 36-220

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-711 Fluid Dynamics

Fall: 12 units
This course focuses on development and application of control volume forms of mass, momentum and energy conservation laws, differential forms of these laws in Eulerian and Lagrangian coordinates, and Navier-Stokes equations. Students also explore applications to problems in incompressible and compressible laminar flows, boundary layers, hydrodynamic lubrication, transient and periodic flows, thermal boundary layers, convective heat transfer, and aerodynamic heating. 4 hrs. lec. Prerequisites: 24-701 or permission of the instructor.
Prerequisite: 24-701

Course Website: https://www.meche.engineering.cmu.edu/

24-718 Computational Fluid Dynamics

Fall: 12 units
This course focuses on numerical techniques for solving partial differential equations including the full incompressible Navier-Stokes equations. Several spatial-temporal discretization methods will be taught, namely the finite difference method, finite volume method and briefly, the finite element method. Explicit and implicit approaches, in addition to methods to solve linear equations are employed to study fluid flows. A review of various finite difference methods which will be used to analyze elliptic, hyperbolic, and parabolic partial differential equations and the concepts of stability, consistency and convergence are presented at the beginning of the course to familiarize the students with general numerical methods. Detailed syllabus of the course is provided on the URL given below. 4 hr. lec
Prerequisites: 24-311 and 24-231

Course Website: http://www.andrew.cmu.edu/user/satbirs/24718/

24-721 Advanced Thermodynamics

Intermittent: 12 units
The course covers advanced macroscopic thermodynamics and introduces statistical thermodynamics. Review of first and second laws. Axiomatic formulation of macroscopic equilibrium thermodynamics and property relationships. Criteria for thermodynamic equilibrium with application to multiphase and multi-component systems. Thermodynamic stability of multiphase systems. Elementary kinetic theory of gases and evaluation of transport properties. Statistical-mechanical evaluation of thermodynamic properties of gases, liquids, and solids. Students are expected to have an undergraduate level of understanding of Thermodynamics (comparable to 24-221). 4 hrs. lec.
Prerequisite: 24-221

Course Website: http://www.andrew.cmu.edu/user/venkatv/24721/

24-722 Energy System Modeling

Fall: 12 units
This course focuses on the thermodynamic modeling of energy systems with emphasis on energy/availability analysis techniques. These techniques are developed and applied to both established and emerging energy technologies, such as internal combustion engines, gas- and coal-fired power plants, solar and wind energy systems, thermochemical hydrogen production cycles, and fuel cells. The course will also consider the integration of components such as reformers and electrolyzers. Modern computational tools are used throughout the course. The course culminates with a group project that requires developing sophisticated, quantitative models of an integrated energy system. Students are expected to have completed an undergraduate course in thermodynamics comparable to 24-221.
Prerequisites: 24-221 or 27-215 or 06-221

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-727 Special Topics: Aerosol Measurement Technology

Intermittent: 12 units
This course explores modern methods and instrumentation used to characterize key physical and chemical properties of aerosol particles, and the fundamental principles underlying the technology. Topics include particle sampling and collection (aerosol inlets, impactors, cyclones, virtual impactors, collection on substrates, electrostatic precipitation), aerosol charging and neutralization, particle size measurements (electrical mobility, optically, and aerodynamically based), particle detection (optical and electrical), aerosol optical properties, and the characterization of particle chemical composition (online mass spectrometry, in particular). Methods for analyzing both individual and ensembles of aerosol particles are discussed and compared. Recent advances reported in the literature are explored through student-led presentations. Students write a term paper describing and justifying their choice of techniques to solve a realistic aerosol measurement need. While the focus is on atmospheric aerosol particles, industrial applications such as particle synthesis and characterization are also discussed.

Course Website: http://www.cmu.edu/me/

24-730 Advanced Heat Transfer

Spring: 12 units
This course is open to students from all areas of engineering, although an undergraduate background in heat transfer is assumed. This class is an appropriate preparation for the doctoral qualifying exam.Topics to be covered include: mathematical formulation of heat transfer problems, heat conduction, thermal radiation, hydraulic boundary layers, and laminar and turbulent convection. Problems and examples will include theory and applications drawn from a spectrum of engineering design problems. Prerequisite: Undergraduate Heat Transfer 24-322 or equivalent.
Prerequisite: 24-322

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-740 Combustion and Air Pollution Control

Intermittent: 12 units
24-740 Combustion and Air Pollution Control This course examines the generation and control of air pollution from combustion systems. The course's first part provides a brief treatment of combustion fundamentals, including thermochemical equilibrium, flame temperature, chemical kinetics, hydrocarbon chemistry, mass transfer, and flame structure. This foundation forms the basis for exploring the formation of gaseous (oxides of nitrogen, carbon monoxide, hydrocarbons, and sulfur dioxide) and particulate pollutants in combustion systems. The course then describes combustion modifications for pollutant control and theories for pollutant removal from effluent streams. The internal combustion engine and utility boilers serve as prototypical combustion systems for discussion. The course also addresses the relationship between technology and the formulation of rational regional, national, and global air pollution control strategies. Cross listed 19-740, 19-440, 24-425

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-751 Solid Mechanics and Elasticity

Fall: 12 units
This introductory course develops the fundamental concepts of continuum mechanics for solids in a manner useful for applications in engineering. Physical understanding of elasticity theory is introduced from first principles in kinematics, stress, and material constitutive laws with a focus on understanding and solving important problems in solids. Topics covered include linear elastic bodies; slender structures of rods and plates; finite deformation of rubbery materials; fracture and adhesion; contact mechanics; and dynamics. Emphasis is placed on using elasticity theory to not only solve classical problems but to also construct and understand experimental results and finite element method simulations in applied engineering applications and fundamental scientific research.

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-753 Special Topics: Robotic Materials: Designs, Principles & Mechanics

Fall and Spring: 12 units
This is an interdisciplinary course focused on principles, theoretical models, and material architectures relevant to applications of condensed soft matter to problems in engineering. Special attention will be given to the design of soft, elastically-deformable machines and electronics that are primarily composed of elastomers, gels, fluids, gas, and other non-rigid matter. Specific topics will include the mechanics of hyperelastic solids, statistical mechanics of polymers and polymer composites, energy-based modeling techniques derived from the Laws of Thermodynamics, and their applications in modeling soft multifunctional material systems. Additionally, we will explore emerging paradigms in soft robotics, wearable computing, and human machine interaction, including material architectures for artificial muscles, stretchable electronics, and sensorized robotic skin. This course will include extensive reading with problem set assignments, a take-home exam, and final report. Students need familiarity with undergraduate-level solid mechanics, vector mechanics, thermodynamics, and ODEs
Prerequisite: 24-751

24-755 Finite Elements in Mechanics I

Fall: 12 units
The basic theory and applications of the finite element method in mechanics are presented. Development of the FEM as a Galerkin method for numerical solution of boundary value problems. Applications to second-order steady problems, including heat conduction, elasticity, convective transport, viscous flow and others. Introduction to advanced topics, including fourth-order equations, time dependence and nonlinear problems. 12 Units Prerequisite(s): Graduate standing or consent of instructor

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-760 Robot Dynamics and Analysis

Fall: 12 units
This course covers the dynamics of robotic systems with a focus on the mathematical structure of the dynamics and numerical analysis. Topics will start by reintroducing basic kinematics and dynamics in a more formal mathematical framework before moving on to contact conditions, friction, hybrid dynamical systems, simulation, and trajectory optimization. After the course students will be able to write simulation and optimization methods for analyzing robotic systems. Students should have taken a prior course in dynamics, and be comfortable with linear algebra, multivariable calculus, and programming in Matlab.
Prerequisites: 16-711 or 24-351

Course Website: http://www.andrew.cmu.edu/user/amj1/classes/robotdynamics.html

24-771 Linear Systems

Fall: 12 units
Topics include review of classical feedback control; solution of differential and difference equations; Laplace and Z-transforms, matrix algebra, and convolution; state variable modeling of dynamic continuous and discrete processes; linearization of nonlinear processes; state variable differential and difference equations; computer-aided analysis techniques for control system design; state variable control principles of controllability, observability, stability, and performance specifications; trade-offs between state variable and transfer function control engineering design techniques; and design problems chosen from chemical, electrical, and mechanical processes. 4 hrs. lec. Prerequisite: An undergraduate course in classical control engineering or consent of the instructor.
Prerequisite: 24-451

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-773 Multivariable Linear Control

Spring: 12 units
Robust control techniques are used in various industries, from hard disk drives to robotics, to rigorously account for model uncertainty and manufacturing variations. This course will introduce robust control of multi-input, multi-output linear systems, providing a synthesis of frequency-domain concepts from classical control with state space analysis from linear systems. Topics include performance limitations in control systems, uncertainty models, generalized plants, robust stability and performance measures, controller synthesis, and model order reduction. The course will mix theoretical developments with practical design examples drawn from industry (robotics, data storage, aerospace, etc.). This is intended to be the 2nd in a three course sequence designed to prepare students for an industrial career in control systems engineering.
Prerequisites: 24-771 Min. grade C or 24-677 Min. grade C

Course Website: http://www.cmu.edu/me/

24-774 Advanced Control Systems Integration

Fall: 12 units
This course focuses on the practical implementation of feedback / feedforward controllers. The entire controller design process is presented, including system modeling and identification, compensator design, simulation, and hardware prototyping. This is a project-based course in which students complete the controller design process on a nonlinear, MIMO hardware system. The goal is train students on the system integration skills necessary for success in industry or experimental laboratory work.
Prerequisites: 24-677 Min. grade C or 24-771 Min. grade C

Course Website: http://www.cmu.edu/me/

24-775 Bioinspired Robot Design and Experimentation

Spring: 12 units
This course will give students hands on experience designing, building, and analyzing robotic systems. Through a semester-long project, students will need to propose and test a research hypothesis with an experimental robotic system. Projects will focus on topics in bioinspired robotics and the robot must either test a biological hypothesis using a robot or test a hypothesis about the robot that is based on bioinspired robotic principles. In addition to the project, lectures and homework will cover topics in bioinspired robotics, robotic component design, systems integration, experimental instrumentation, biohybrid robotics, and biomimetic modeling. This class provides the opportunity for students to apply techniques in design, control, and analysis that students have acquired during their graduate studies. Students are expected to be comfortable programming in Matlab and have some prior graduate-level experience in mechanical design, controls, optimization, or robotics.

Course Website: https://www.andrew.cmu.edu/course/24-775/

24-776 Non Linear Control

Intermittent: 12 units
Nonlinear Control (12 Units) This course provides an introduction to the analysis and design of nonlinear systems and nonlinear control systems; stability analysis using Lyapunov, input-output and asymptotic methods; and design of stabilizing controllers using a variety of methods selected from linearization, vibrational control, sliding modes, feedback linearization and geometric control. 4 hrs. lec.
Prerequisite: 24-771

24-778 Mechatronic Design

Spring: 12 units
Mechatronics is the synergistic integration of mechanical mechanisms, electronics, and computer control to achieve a functional system. Because of the emphasis upon integration, this course will center around laboratory projects in which small teams of students will configure, design, and implement mechatronic systems. Lectures will complement the laboratory experience with operational principles and system design issues associated with the spectrum of mechanical, electrical, and microcontroller components. Class lectures will cover selected topics including mechatronic design methodologies, system modeling, mechanical components, sensor and I/O interfacing, motor control, and microcontroller basics.

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-780 Engineering Computation

Fall: 12 units
This course covers the practical programming and computational skills necessary for engineers. These include: (1) programming in C++, (2) visualization using OpenGL, (3) basic data structures, and (4) basic algorithms. The course covers computational techniques required for solving common engineering problems and background algorithms and data structures used in modern Computer-Aided Design, Computer-Aided Manufacturing, and Computer-Aided Engineering tools. The course also offers intensive hands-on computational assignments for practice of common applications.

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-781 Engineering Computation Project

Fall
24-781 This project course is the first section of the two-semester sequence of Computational Engineering Projects. The course provides the students with hands-on problem-solving experience by using commercial computational tools and/or developing their own custom software. Each student, individually or along with other students, will work on a project under the guidance of Carnegie Mellon faculty members and/or senior engineers from industry. Students may select a project topic from those presented by advising faculty members and/or industry engineers. Alternatively, a student may propose and work on his/her own project topic if he/she can identify a sponsoring faculty member or industry engineer.

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-782 Machine Learning and Artificial Intelligence for Engineers - Project

Spring: 12 units
This course provides an open-ended computational project experience in artificial intelligence and machine learning. This course will enable student teams to design, develop and test data-driven computational algorithms. Course objectives are: - Gain experience in data sciences and data-driven methods for engineering. - Learn advanced programming and computational system design. - Learn project planning and management, project evaluation, teamwork, technical communication. The projects will target problems involving experimental, simulated or crowd-sourced data. Each project will aim to build an artificial intelligence or machine learning system that accomplishes one or more of the following: Identify patterns in data, establish a mathematical model for the input/output relationships, classify data into distinct categories, use existing data to synthesize new solutions to a synthesis problem. Team activities include three presentations, two written reports, a final technology demo, and one final report in the form of an archival publication.
Prerequisites: 10-701 Min. grade C or 15-781 Min. grade C or 10-601 Min. grade C or 24-787 Min. grade C

Course Website: http://www.cmu.edu/me/

24-783 Advanced Engineering Computation

Spring: 12 units
This course covers the advanced programming and computational skills necessary for solving engineering problems. These include (1) efficient data structures and algorithms for modeling and processing real-world data sets such as trees, hash tables, searching, priority queues, etc. (2) techniques for simulation and visualization such as numerically solving ODEs and PDEs, viewing control, programmable shader, etc., (4) tools for version controlling, scripting, and code building including sub-version, git, and cmake. Students will experience practical training in the above knowledge and programming skills through bi-weekly assignments and a final team project. Prerequisites- 24-780 Engineering Computation or equivalent C++ and OpenGL programming experience
Prerequisite: 24-780

Course Website: http://www.cmu.edu/me/

24-784 Special Topics: Trustworthy AI

Intermittent: 12 units
Innovations driven by recent progress in artificial intelligence such as deep learning and reinforcement learning, have shown human-competitive performance. However, as research expands to real-world cyber-physical autonomy, the question of safety is becoming a crux for the transition from theories to practice. This course will first review fundamental knowledge for trustworthy AI autonomy, including adversarial attack/defend, generative models, hierarchical Bayesian models, safe reinforcement learning, rare-event/few-shot learning, and robust evaluation. Then from the research perspective, students will explore the novelty and potential extension of various state-of-the-art trustworthy AI research and their implementation through a series of readings. Students will develop the ability to conduct research in teams. Knowledge and research skills learned in this course can be applied to self-driving, healthcare devices, assistant robots, and intelligent manufacturing. This course is devised for research-focused students who have backgrounds and interests in statistical machine learning, robotics and control, and human-machine interaction. Other interested students should contact the instructor to determine if it is a good fit for them.

24-785 Engineering Optimization

Intermittent: 12 units
Engineering Optimization Intermittent: 12 units This course introduces students to 1) the process of formally representing an engineering design or decision-making problem as a mathematical problem and 2) the theory and numerical methods needed to understand and solve the mathematical problem. Theoretical topics focus on constrained nonlinear programming, including necessary and sufficient conditions for local and global optimality and numerical methods for solving nonlinear optimization problems. Additional topics such as linear programming, mixed integer programming, global optimization, and stochastic methods are briefly introduced. Model construction and interpretation are explored with metamodeling and model reformulation techniques, study of model boundedness, constraint activity, and sensitivity analysis. Matlab is used in homework assignments for visualization and algorithm development, and students apply theory and methods to a topic of interest in a course project. Fluency with multivariable calculus, linear algebra, and computer programming is expected. Students who are unfamiliar with Matlab are expected to learn independently using available tutorials and examples provided. 4 hrs.lecture Prerequisites: None 19785 and 24785: 12-units including the team-based engineering optimization project 19685 and 24685: 9-units excluding the project
Prerequisites: 21-341 and 21-259

24-787 Machine Learning and Artificial Intelligence for Engineers

Fall: 12 units
This course introduces fundamental machine learning and artificial intelligence techniques useful for engineers working on data-intensive problems. Topics include: Probability and Bayesian learning, generative and discriminative classification methods, supervised and unsupervised learning, neural networks, support vector machines, clustering, dimensionality reduction, regression, optimization, evolutionary computation, and search. The lectures emphasize the theoretical foundations and the mathematical modeling of the introduced techniques, while bi-weekly homework assignments focus on the implementation and testing of the learned techniques in software. The assignments require knowledge of Python including text and image input/output, vector and matrix operations, simple loops, and data visualization. Students must have undergraduate level experience with linear algebra and vector calculus.
Prerequisites: (21-341 and 15-112) or (15-112 and 21-254)

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-788 Introduction to Deep Learning

Spring: 6 units
This course introduces the deep learning methodology. Students will learn about the basics of deep neural networks, and their applications to different tasks in engineering. Students will be able to apply Deep Learning to a variety of artificial intelligence tasks pertinent to different engineering problems. Neural Networks and Convolutional Neural Networks (CNN) and different variations of it will be taught. The fundamental knowledge and mathematics behind backpropagation and automatic differentiation will be discussed. Deep learning libraries such as Pytorch will be taught, and students will learn to use these libraries for developing deep learning models.
Prerequisites: 10-601 or 24-787 or 10-715 or 18-611 or 10-701

Course Website: http://www.cmu.edu/me/

24-789 Intermediate Deep Learning for Engineers

Spring: 6 units
This course will introduce some of the advances in deep learning technology such as sequential learning using Recurrent Neural Networks, Generative Adversarial Networks, Attention models and Transformers, and Diffusion models. Students will learn how to implement these models using deep learning libraries (Pytorch). Introduction to deep learning is the prerequisite.
Prerequisites: (24-787 or 10-601 or 11-785 or 10-715) and (24-788 or 11-785)

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-790 Thesis Research

Intermittent
This course is designed to give students enrolled in the Ph.D. program an opportunity to conduct extensive research over the course of their studies. Variable hrs.

24-791 Graduate Seminar

All Semesters
Graduate seminar speakers include faculty, students, and invited guests from industry and academia. Through seminars, students widen their perspectives and become more aware of other topics in mechanical engineering

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-793 Supervised Reading

Fall and Spring
This independent study is designed to give students an opportunity to explore pertinent subjects through faculty directed reading. Variable hrs. Prerequisite: Completion of "Supervised Reading" form acquired by your graduate MechE advisor; which includes permission of the instructor.

Course Website: https://www.meche.engineering.cmu.edu/education/graduate-programs/index.html (https://www.meche.engineering.cmu.edu/education/graduate-programs/)

24-794 Master of Science Research

Fall and Spring
This course is designed to be a training opportunity in engineering research and associated professional activity. Content includes a series of investigations under the student's initiative culminating in comprehensive reports, with special emphasis on orderly presentation and effective English composition for Master of Science candidates. Variable hrs. Prerequisite: permission of the instructor.

Course Website: https://www.meche.engineering.cmu.edu/education/graduate-programs/index.html (https://www.meche.engineering.cmu.edu/education/graduate-programs/)

24-795 PhD Internship in Teaching Counterpoint

Fall and Spring
A teaching assignment under the guidance of a faculty member for intermediate or terminal-level doctoral candidates. Typical activities include preparing and teaching recitations, preparing and teaching laboratory sessions, holding office hours, grading and preparation of quizzes, problem sets and other assignments, and assisting instructor with other activities associated with teaching a course. 24-795 is 12 units and offered in Fall and Spring (P/F). All non-native English speakers must conform to the university regulation on the TA language requirements.

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-797 Thesis Research

Fall and Spring
This course is designed to give students enrolled in the Ph.D. program an opportunity to conduct extensive research over the course of their studies. Variable hrs.

Course Website: http://www.cmu.edu/me/graduate/index.html (http://www.cmu.edu/me/graduate/)

24-799 Practicum in Mechanical Engineering

All Semesters
The Department of Mechanical Engineering at Carnegie Mellon considers experiential learning opportunities important educational options for its graduate students. One such option is an internship, normally completed during the summer. If a student receives an internship, the Mechanical Engineering Department will add the internship course to the student's schedule, and the student will be assessed tuition for 3 units. Upon completion of the internship, students must submit a 2-3 page report with supervisor signature detailing the work experience and including how the internship was related to Mechanical Engineering. After the report has been reviewed and approved, a letter grade will be assigned and these 3 units will count towards degree requirements. International students interested in registering for the practicum must also be authorized for Curricular Practical Training (CPT). Further information is available on the Office of International Education?s website: www.cmu.edu/oie.

Course Website: https://www.meche.engineering.cmu.edu/education/graduate-programs/index.html (https://www.meche.engineering.cmu.edu/education/graduate-programs/)

24-850 Implantable Cell-Based Medical Devices

Fall: 12 units
This advanced seminar course explores the emerging field of implantable medical devices that utilize living cells to deliver therapeutics and/or continuously monitor patient's health through key biomarkers. After discussing requirements for such devices, the course will examine the literature on various aspects, including design principles, material requirements, cell engineering and selection, cell encapsulation and protection, supporting long-term cell viability and functionality in vivo. We will then discuss various current and emerging applications of those devices from targeted drug delivery for various diseases to continuous biomarker monitoring enabling personalized treatment strategies. We will conclude by examining the regulatory pathways and clinical trials necessary to bring these groundbreaking devices to patients.

24-892 Locomotion Seminar

Intermittent
The CMU Bipedal Locomotion Seminar is a weekly meeting amongst students and professors who study bipedal locomotion using a variety of approaches. Each week, one graduate student participant gives a presentation on a topic of their choosing related to their research. We encourage discussion and interaction, especially from fellow students. Each meeting is intended to work like a small, informal conference discussion or workshop, providing students with new perspectives on their projects, practice presenting and answering questions, and a forum for meeting colleagues. We encourage participation from all interested students and faculty, including members of Carnegie Mellon, The University of Pittsburgh, and Disney Research Pittsburgh. Please join the waitlist and contact one of the instructors for admission.

Course Website: http://www.andrew.cmu.edu/user/amj1/locomotion_seminar.html

24-991 Professional Development for PhD students

Fall: 2 units
This course is the first in a sequence of two required courses where incoming PhD students learn research and professional communication skills that will benefit them throughout the PhD and in their careers. Topics covered include DEI and cross-cultural communication, reading and understanding technical publications, building the student/advisor relationship, working in teams, communicating by email, presenting for success, receiving and addressing critical feedback, and performing a literature review. The class intends to strengthen the PhD cohort and activities will often require group work and evaluation.

24-992 Professional Development for PhD students II

Spring: 2 units
This is one of two required courses (the other being 24-991) where incoming PhD students learn research and professional skills that will benefit them throughout the PhD and in their careers. Topics covered include leadership and equity in teamwork, equity in evaluation, ethics in research, presenting your work to different audiences, responding to questions in an oral presentation, responding to peer review, and writing an effective abstract. The class intends to strengthen the PhD cohort and activities will often require group work and evaluation. Students entering in the Spring should take 24-992 before 24-991

Engineering Minors for Non-Engineering Students

Biomedical Engineering Minor

Kristin Kropf, *Undergraduate Program and Alumni Relations Coordinator, Biomedical Engineering*
kgaluska@andrew.cmu.edu
www.cmu.edu/bme/Academics/undergraduate-programs/minor.html (https://www.cmu.edu/bme/Academics/undergraduate-programs/minor.html)

The minor program is designed for students who desire exposure to biomedical engineering but may not have the time to pursue the Biomedical Engineering additional major. The program is open to students of **all** colleges and is popular among both engineering and science majors. In conjunction with other relevant courses, the program may provide a sufficient background for jobs or graduate studies in biomedical engineering. Students interested in a medical career may also find this program helpful.

The Biomedical Engineering minor curriculum is comprised of three core courses and three electives. The Quality Point Average (QPA) for courses that count toward the minor must be 2.00 or better. No course taken on a pass/fail or audit basis may be counted towards the minor.

Students who have questions or are interested in declaring Biomedical Engineering minor should contact Kristin Kropf (kgaluska@andrew.cmu.edu).

Requirements

Minimum units required for minor:		57
03-121	Modern Biology	9
or 03-151	Honors Modern Biology	
42-101	Introduction to Biomedical Engineering	12
42-202	Physiology	9
42-xxx	BME Elective I	9-12
42-xxx	BME Elective II	9-12
42-xxx	BME Elective III	9-12

A BME Elective is defined as one of the following:

1. One semester of 42-200 Sophomore BME Research Project, 42-300 Junior BME Research Project, 42-400 Senior BME Research Project or 39-500 Honors Research Project. The project must be supervised by a core or courtesy Biomedical Engineering faculty member and for 9 or more units. Research projects supervised by a courtesy Biomedical Engineering faculty member must have significant biomedical engineering relevance. Note that BME Research Project can only be count as one BME elective.

2. 42-203 BME Laboratory (or the cross-listed version 03-206 for students in the Health Professions Program). Please note that priority for enrollment in 42-203 or 03-206 will be given to students who have declared the Additional Major in Biomedical Engineering. If sufficient room in the course remains after all majors have been accommodated in a given semester, students who have declared the Biomedical Engineering Designated Minor will be given the next priority for enrollment. If space still allows, other students will be enrolled.

3. Any 42-xxx course with a course number greater than 42-300 and worth at least 9 units (excluding 42-300 and 42-400- see previous comment regarding BME Research Project).

Students can petition the Biomedical Engineering Undergraduate Affairs Committee to count non-BME classes that have significant biological or medical content towards the minor requirements.

Engineering Studies Minor

(for non-engineering students)

Kurt Larsen, *Director*
Location: Scaife Hall 426

Carnegie Mellon undergraduate students enrolled in colleges other than engineering can complete a Minor in Engineering Studies in addition to their regular majors. Students pursuing this minor are required to complete courses from at least two different engineering departments in order to assure some breadth of exposure to engineering. In addition, the minor provides students the opportunity to pursue an in-depth concentration in a particular field of engineering.

For the Minor in Engineering Studies, students must complete five engineering courses as follows and must earn a cumulative QPA of 2.00 in these five courses. Students may declare the minor by contacting the director after they have successfully completed one introductory engineering courses (from list #1 below).

Requirements

1. At least one and up to three of the following:

12-100	Exploring CEE: Infrastructure and Environment in a Changing World	12
18-100	Introduction to Electrical and Computer Engineering	12
19-101	Introduction to Engineering and Public Policy	12
24-101	Fundamentals of Mechanical Engineering	12
27-100	Engineering the Materials of the Future	12
42-101	Introduction to Biomedical Engineering	12

2. Four engineering-centric courses of at least nine units each. Students must demonstrate both breadth and depth by taking courses from at least two of the below departments; and at least two courses from the same department.

- Biomedical Engineering
- Chemical Engineering
- Civil and Environmental Engineering
- Electrical and Computer Engineering
- Engineering Design, Innovation, and Entrepreneurship
- Engineering and Public Policy*
- Materials Science and Engineering
- Mechanical Engineering

Up to one of the following Robotics courses can count toward the ES minor. But it cannot be double-counted with the Robotics minor or double major.

1.

16-311	Introduction to Robotics	12
16-362	Mobile Robot Algorithms Laboratory	12
16-384	Robot Kinematics and Dynamics	12
16-385	Computer Vision	12
16-421	Vision Sensors	12
16-474	Robotics Capstone	12
16-350	Planning Techniques for Robotics	12

NOTE: The following courses may NOT be included as part of the minor in Engineering Studies.

06-262	Mathematical Methods of Chemical Engineering	12
12-201	Geology	9
15-213	Introduction to Computer Systems	12
18-090	Twisted Signals: Multimedia Processing for the Arts	10
18-200	ECE Sophomore Seminar	1
18-202	Mathematical Foundations of Electrical Engineering	12

18-213	Introduction to Computer Systems for a core major requirement (e.g. CS minor)	12
24-280	Special Topics: C++ Programming for Engineers	9
24-291	Environmental Systems on a Changing Planet	9
24-311	Numerical Methods	10
42-202	Physiology	9

Double counting of core courses in student's primary major is not permitted.

*Because of the nature of the courses offered by Engineering and Public Policy, only two EPP courses (including 19-101) can be used toward the minor requirements. Most EPP courses (19-xxx) are not permissible for the minor; students need special permission to use 19-xxx toward this minor and should contact the director for prior approval. Students interested in EPP coursework should consider the Technology and Policy minor instead.

Technology and Policy Minor

Deanna H. Matthews, *Associate Department Head for Undergraduate Affairs, Engineering and Public Policy*
Location: Wean Hall 4101

The Technology and Policy Minor is administered by the Department of Engineering and Public Policy (EPP). The Technology and Policy Minor is designed to give students a basic understanding of the interactions between technology, society and policy and some project experience in problems involving technology and policy.

Pre-requisites

Students should have prerequisite knowledge in economics (73-102 Principles of Microeconomics or similar level economics course) and statistics (36-202 Methods for Statistics & Data Science or similar level statistics course) in order to pursue the Technology and Policy Minor.

Course Requirements

19-101	Introduction to Engineering and Public Policy	12
19-301	Decision Making Methods for Engineers and Scientists or other approved Decision Science course	9
or 19-351	Applied Methods for Technology-Policy Analysis	
19-451	EPP Projects I	12
xx-xxx	Two EPP Technology-Policy Electives	18

EPP Technical Electives include courses that address problems at the society-technology interface and the means of analyzing these issues. A list of qualifying Technology-Policy electives is assembled each semester and is available from the EPP Department. Example Technology-Policy electives include:

19-211	Ethics and Policy Issues in Computing	9
19-303	Cryptocurrencies, Blockchains and Applications	Var.
19-403	Policies of Wireless Systems	12
19-411	Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech	9
19-425	Sustainable Energy for the Developing World	9
19-429	Climate Change Science and Solutions	9
19-433	Data Science for Technology, Innovation and Policy	9
19-469	Behavior, Decision and Policy	9
19-639	Policies of the Internet	12
19-668	Electric Vehicles: Technology, Economics, Environment and Policy	12

Students must earn a cumulative QPA of 2.0 in all courses taken for the minor. Required courses taken for a student’s primary major may not be counted toward the Technology and Policy Minor. Elective courses for a student’s primary major or courses fulfilling general education requirements may be counted, however.

Information Security, Privacy and Policy Minor

Lujo Bauer, *Professor, Electrical and Computer Engineering and Software and Societal Systems Department (SCS)*

Deanna H. Matthews, *Associate Department Head for Undergraduate Affairs, Engineering and Public Policy*

Interdisciplinary minor offered by both CIT and SCS

There is a growing demand for security and privacy experts, and increasing interest among CMU undergraduates in taking security and privacy courses. Security and privacy expertise is an asset in a variety of careers outside, not just in computer science, but also in areas that include business, management, and law. In addition, the policy side of security and privacy is becoming increasingly important and employers are interested in hiring people with an understanding of relevant policy issues, especially in the privacy and security area.

This minor is for undergraduate students across the university who are interested in policy issues related to security and privacy, including those who are planning careers in security/privacy as well as those who plan to focus their careers in other areas. The curriculum has been designed to accommodate students from any major as long as they have taken at least one introductory-level college programming course (such as 15-110 or 15-112).

After completing this minor, students will have a good understanding of how to identify potential security and privacy risks and relevant legal and policy issues; a working understanding of security topics such as cryptography, authentication, and Internet security protocols; as well as broad knowledge of several security- and privacy-related areas as they pertain to the design, development, deployment and management of technologies in a variety of practical contexts (e.g., Web, mobile, Internet of Things, social media, crypto currencies).

Admission

Students are not required to apply to enroll in this minor to start the required courses. However, they are encouraged to consult with the minor director on their elective course selection. In addition, students doing the independent study option must get approval from the minor director prior to enrolling in their independent study course. Finally, students must contact the minor director to certify their completion of the minor.

Curriculum

Students are required to take five courses to complete this minor with a minimum of 48 units.

INTRODUCTORY SECURITY COURSE

17-331	Information Security, Privacy, and Policy	12

Students who have taken 15-213 Introduction to Computer Systems may substitute 15-330 Introduction to Computer Security/18-330 Introduction to Computer Security

PRIVACY AND POLICY COURSE

17-333	Privacy Policy, Law, and Technology	9

Students may substitute a 12-unit version of this course: 19-608, 17-333, or 95-818.

PRIVACY ELECTIVES

Complete a minimum of 9 units:		
19-534/17-334	Usable Privacy and Security	9
19-602/17-702	Current Topics In Privacy Seminar	3
17-731	Foundations of Privacy	12

TECHNOLOGY AND POLICY ELECTIVES

Complete a minimum of 9 units:		Units
19-211	Ethics and Policy Issues in Computing	9
17-562	Law of Computer Technology	9
19-101	Introduction to Engineering and Public Policy	12
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-403	Policies of Wireless Systems	12
19-639	Policies of the Internet	12
84-387	Remote Systems and the Cyber Domain in Conflict	9

Crosslisted courses are also allowed.

ADDITIONAL APPROVED ELECTIVE

Students must complete an additional elective of 9 units or more. Students may choose an additional privacy elective or technology policy elective from the list above, or the one of the following security electives:

15-316	Software Foundations of Security and Privacy	9
15-356	Introduction to Cryptography	12
19/17-303	Cryptocurrencies, Blockchains and Applications	Var.
19-534/17-334	Usable Privacy and Security	9
18-334	Network Security	12
18-335	Secure Software Systems	12
18-435	Foundations of Blockchains	12

Students who have the necessary prerequisites may choose any approved elective from the SCS or ECE security and privacy undergraduate concentration. Check with the minor program director to determine which category of elective each course will fulfill.

Students should be careful to choose electives for which they have appropriate prerequisites. New elective options are expected as more courses are offered. Students may petition to count a course not on this list as an elective. Students should request permission *before* taking a course that is not on this list. Students may not count multiple electives that overlap substantially.

Optional Project: Subject to approval by the minor director, students may optionally count towards one of the elective requirements 9 units of an independent study or research project course in the security or privacy area, under the supervision of a faculty member in any department. In order to receive credit towards the minor, students must submit a brief project proposal to their project advisor and to the minor director and have it approved prior to conducting the project. Depending on the topic of the project, the minor director may approve credits counting towards privacy electives, technology policy electives, security electives, or some combination of these. Students may work individually, with other undergraduates, or as part of project teams with graduate students or research staff. Students involved in a group project must identify specific project components for which they are responsible. In addition, they must submit a final project report to their project advisor and the minor director that includes a literature review and describes the work they completed. Students working on a group project must each submit their own final report, which should also situate their contribution in the context of the larger project. Note, students are expected to work approximately 1 hour per week for each unit of project in which they are enrolled (e.g. 9 units = 9 hours/week of project work).

Double Counting: At most 2 of the courses used to fulfill the minor requirements may be counted towards any other undergraduate major or minor program. This rule does not apply to courses counted for general education requirements.

Undergraduate Designated Minors in the College of Engineering

Overview

Undergraduate students in the Carnegie Institute of Technology can elect to complete an interdisciplinary Designated Minor in addition to their regular majors for B.S. degrees. Designated minors have been added to the curriculum of the Carnegie Institute of Technology to promote flexibility and diversity among the college's engineering students. Independent of a student's major, he or she is able to pursue a selected designated minor from the following list:

- Additive Manufacturing
- Audio Engineering
- Biomedical Engineering
- Colloids, Polymers and Surfaces
- Electronic Materials
- Global Engineering
- Materials Science and Engineering
- Mechanical Behavior of Materials

An engineering student may elect to complete a CIT designated minor. Generally, the student takes all the required courses in an engineering major but uses electives to take courses needed to fulfill the requirements of the designated minor. Upon completion of the requirements of a CIT designated minor and the engineering degree, the minor is a formally recognized on the student's transcript.

Each of the CIT designated minors is administered by a Program Committee consisting of faculty from all major engineering departments who serve as faculty advisors. Each Program Committee certifies the completion of requirements of the designated minor. But the student's major department is responsible for approving the degree with a designated minor after reviewing a student's entire academic record. Any substitution or departure from the published curriculum should be avoided. For example, non-technical courses may not be substituted for required technical courses or electives. Equivalent technical electives offered by a designated minor as substitutions for required courses in a major must be approved by the Head of the student's major department.

Although a student generally can complete a designated minor without increasing the number of required units for graduation, early planning in electing a designated minor is important. A student also may find that some minors are more compatible than others with his/her major because of different relations between various major and minor requirements. The requirements for these CIT designated minors are listed below.

Additive Manufacturing Minor

The objective of the Minor in Additive Manufacturing is to provide the student with a background in the engineering science that applies to additive manufacturing (also known as 3D printing), from part design through additive processes, to properties and component performance. Particular emphasis is given to metals additive manufacturing, due to its rapidly growing impact on manufacturing across multiple industries, and the need for talent in this area. The minor is open to students in all engineering majors.

Students may not use any given course to satisfy simultaneously requirements in both their enrolled major and in this minor. Graduate courses counted towards this minor may not be (double) counted for a graduate degree.

Minor Coordinators

Paige Houser, Academic Advisor

Departmental Contacts

Biomedical Engineering	**Robert Tilton**
Chemical Engineering	**Robert Tilton**
Electrical and Computer Engineering	**Maysam Chamanzar**
Engineering and Public Policy	**Deanna Hart Matthews**
Materials Science and Engineering	**Anthony Rollett**
Mechanical Engineering	**Jack Beuth**

Course Requirements

This minor requires a total of five (5) courses comprising of three core courses and two technical electives.

Three Core Courses 36 units

		Units
39-601	Special Topics: Additive Manufacturing Processing and Product Development	12
39-602	Additive Manufacturing and Materials	12
39-603	Additive Manufacturing Laboratory	12

Two Technical Electives

To select acceptable technical elective course options, please speak with your departmental contact, or see https://engineering.cmu.edu/education/undergraduate-programs/curriculum/additive-manufacturing-minor.html.

Audio Engineering Minor

Tom Sullivan, *Director and Faculty Advisor*

This sequence is for candidates who are engineering majors with interest in and/or have background in music, recording, sound-editing and/or other music technology areas; or majors from any discipline in the university who have the above interests and who can meet the prerequisite requirements for the engineering courses in the minor.

Note: Students who do not have the requisite engineering/science/math background should investigate the Minor in Music Technology offered by the School of Music.

Course Requirements

Minimum units required for minor: 73-79

The student must have taken the appropriate prerequisite courses for the listed courses.

Prerequisite Courses, 0-3 units

Beginning Piano is required of students who do not pass a piano proficiency test.

		Units
57-103	Elective Studio (Beginning Piano Class)	3

Music Courses, 43-49 units

Basic Harmony I is required of students who do not qualify for entrance into Harmony I, based on their scores on the theory placement test.

		Units
57-101	Introduction to Music Technology	6
or 57-171	Introduction to Music Technology (self-paced)	
57-149	Basic Harmony I	9
or 57-152	Harmony I	
57-173	Survey of Western Music History *	9
57-188	Repertoire and Listening for Musicians	1
57-337	Sound Recording	6

* co-requisite 57-188.

(choose two of the courses below)		Units
15-322	Introduction to Computer Music	9
57-338	Sound Editing and Mastering	6
57-347	Electronic and Computer Music	6
57-438	Multitrack Recording	9

Technical Courses, 33 units

Other courses may be taken with the approval of the Audio Engineering Minor Advisor.

		Units
33-114	Physics of Musical Sound	9
18-490	Electroacoustics **	12

** prerequisites 18-220 and 18-290.

(choose one of the courses below)		Units
18-300	Fundamentals of Electromagnetics	12
18-341	Logic Design and Verification	12
18-370	Fundamentals of Control	12
18-491	Digital Signal Processing	12
15-210	Parallel and Sequential Data Structures and Algorithms	12
15-214	Principles of Software Construction: Objects, Design, and Concurrency	12
18-320	Microelectronic Circuits +	12
18-349	Introduction to Embedded Systems ***	12

+ prerequisite 18-220.

*** prerequisites 18-240 and 18-213.

Biomedical Engineering Minor

Kristin Kropf, *Undergraduate Program and Alumni Relations Coordinator, Biomedical Engineering*
kgaluska@andrew.cmu.edu
www.cmu.edu/bme/Academics/undergraduate-programs/minor.html (https://www.cmu.edu/bme/Academics/undergraduate-programs/minor.html)

The minor program is designed for students who desire exposure to biomedical engineering but may not have the time to pursue the Biomedical Engineering additional major. The program is open to students of **all** colleges and is popular among both engineering and science majors. In conjunction with other relevant courses, the program may provide a sufficient background for jobs or graduate studies in biomedical engineering. Students interested in a medical career may also find this program helpful.

The Biomedical Engineering minor curriculum is comprised of three core courses and three electives. The Quality Point Average (QPA) for courses that count toward the minor must be 2.00 or better. No course taken on a pass/fail or audit basis may be counted towards the minor.

Students who have questions or are interested in declaring Biomedical Engineering minor should contact Kristin Kropf (kgaluska@andrew.cmu.edu).

Requirements

Minimum units required for minor: 57

03-121	Modern Biology	9
or 03-151	Honors Modern Biology	
42-101	Introduction to Biomedical Engineering	12
42-202	Physiology	9
42-xxx	BME Elective I	9-12
42-xxx	BME Elective II	9-12
42-xxx	BME Elective III	9-12

A BME Elective is defined as one of the following:

1. One semester of 42-200 Sophomore BME Research Project, 42-300 Junior BME Research Project, 42-400 Senior BME Research Project or 39-500 Honors Research Project. The project must be supervised by a core or courtesy Biomedical Engineering faculty member and for 9 or more units. Research projects supervised by a courtesy Biomedical Engineering faculty member must have significant biomedical engineering relevance. Note that BME Research Project can only be count as one BME elective.

2. 42-203 BME Laboratory (or the cross-listed version 03-206 for students in the Health Professions Program). Please note that priority for enrollment in 42-203 or 03-206 will be given to students who have declared the Additional Major in Biomedical Engineering. If sufficient room in the course remains after all majors have been accommodated in a given semester, students who have declared the Biomedical Engineering Designated Minor will be given the next priority for enrollment. If space still allows, other students will be enrolled.

3. Any 42-xxx course with a course number greater than 42-300 and worth at least 9 units (excluding 42-300 and 42-400- see previous comment regarding BME Research Project).

Students can petition the Biomedical Engineering Undergraduate Affairs Committee to count non-BME classes that have significant biological or medical content towards the minor requirements.

Colloids, Polymers and Surfaces Minor

Professor Robert Tilton, *Director of CPS Minor*
Location: Doherty Hall A207C

The sequence of courses in the Colloids, Polymers and Surfaces (CPS) designated minor provides an opportunity to explore the science and engineering of fine particles and macromolecules as they relate to complex fluids and interfacially engineered materials. These topics are very relevant to technology and product development in industries that manufacture pharmaceuticals, coatings and paints, pulp and paper, biomaterials, surfactants and cleaning products, cosmetics and personal care products, food, textiles and fibers, nanoparticles, polymer/plastics, composite materials.

Course Requirements

Minimum units required for minor: 45

This minor requires a total of five classes with a minimum of 45 units. The following four courses are mandatory:

06-609/09-509	Physical Chemistry of Macromolecules	9
06-607	Physical Chemistry of Colloids and Surfaces	9
06-426	Experimental Colloid Surface Science	9
06-466	Experimental Polymer Science	9

In addition, the student must take one CPS related elective course from the following list:

06-612	Formulation Engineering	12
06-610	Rheology and Structure of Complex Fluids	9
09-502	Organic Chemistry of Polymers	9
27-565	Nanostructured Materials	9
27-477	Introduction to Polymer Science and Engineering	9

Other CPS electives are possible but must be approved by the Director of the CPS minor, Professor Tilton

Electronic Materials Minor

Jim Bain, *Co-Director*
Marek Skowronski, *Co-Director*
Paige Houser, *Academic Advisor*

Electronic materials are ubiquitous and essential in 21st century society. They underpin technologies that we rely on everyday – everything from communication, transportation, and lighting to commerce and entertainment. Advances in the synthesis, processing, and design of electronic materials are continuing to push boundaries towards more energy-efficient technologies, such as neuromorphic and quantum computing, long-range electric vehicles, AI, renewable energy sources, and other yet-to-be-discovered applications.

The Electronic Materials (EM) Minor is designed for students who have a keen interest in electronic materials, such as semiconductors, dielectrics and magnetics, and who are considering graduate school studies or careers pertaining to electronic materials industries. Students in the EM Minor will choose from a list of course electives from which they will learn about the physics, chemistry, synthesis, processing, design, characterization, and applications of a wide variety of electronic materials and devices.

Course Requirements

Minimum units for minor 54

54 Units From the Following Electives * :

27-100	Engineering the Materials of the Future ECE students only)	12
or 27-201	Structure of Materials	
or 27-211	Structure of Materials (Minor Option)	
18-100	Introduction to Electrical and Computer Engineering (MSE students only)	12
27-202	Defects in Materials (ECE students only)	9
or 27-212	Defects in Materials (Minor Option)	
27-432	Electronic and Thermal Properties of Metals, Semiconductors and Related Devices	9
27-433	Dielectric, Magnetic, Superconducting Properties of Materials & Related Devices	9
27-445	Structure, Properties and Performance Relationships in Magnetic Materials	9
27-533	Principles of Growth and Processing of Semiconductors	6
27-542	Thin Film Technologies	9
18-220	Electronic Devices and Analog Circuits	12
18-300	Fundamentals of Electromagnetics	12
18-310	Fundamentals of Semiconductor Devices	12
33-225	Quantum Physics and Structure of Matter	9
xx-xxx	An approved special topics or graduate level class pertaining to electronic materials	6-12

xx-xxx	An approved research project on electronic materials	6-12

*Students in ECE must take a minimum of 9 units in MSE, students in MSE must take a minimum of 9 units in ECE.

Global Engineering Minor

Treci Bonime, Director
Office: Scaife Hall 424

Many engineers work on international projects or for multinational companies. Carnegie Mellon is an international community, with a significant fraction of international students and many events featuring foreign speakers and cultural experiences. This minor is intended for engineering students interested in broadening their background in international experiences and global awareness and engagement.

Course Requirements

International Management (1 course)

Complete one course in international management or business such as:

70-342	Managing Across Cultures	9
70-365	International Trade and International Law	9
70-381	Marketing I	9
70-430	International Management	9
Or approved equivalent		

Regional Specialization (1 course)

Complete one course in non-US History, international politics, or literature in a single region of the world. See the list at https://engineering.cmu.edu/education/undergraduate-programs/curriculum/global-courses-minors.htmll (http://www.cit.cmu.edu/global/courses_degrees.html) below for examples (Note: Please consult with the Global Engineering director before planning your course schedule, as some course information may have changed).

Ethics (1 course)

Any ethics course that provides some exposure to international ethics issues such as:

70-332	Business, Society and Ethics	9
80-136	Social Structure, Public Policy & Ethics	9
80-244	Environmental Ethics	9
Or approved equivalent		

Languages, Cultures, and Applied Linguistics

Demonstration of basic competency in a foreign language via one of the three options listed below:

- Complete one (1) Languages, Cultures, and Applied Linguistics course at the 200 level, with a minimum grade of C, or
- Achieve a score of 4 or higher in one foreign language Advanced Placement examination, or
- Demonstrate equivalent proficiency to the satisfaction of the Department of Languages, Cultures, and Applied Linguistics

Study/Work Abroad

Study or engineering internship work abroad for a semester or a summer. The region visited should be consistent with the language and regional culture/history studied.

Information Security, Privacy and Policy Minor

Lujo Bauer, *Professor, Electrical and Computer Engineering and Software and Societal Systems Department (SCS)*

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Interdisciplinary minor offered by both CIT and SCS

There is a growing demand for security and privacy experts, and increasing interest among CMU undergraduates in taking security and privacy courses. Security and privacy expertise is an asset in a variety of careers outside, not just in computer science, but also in areas that include business, management, and law. In addition, the policy side of security and privacy is becoming increasingly important and employers are interested in hiring people with an understanding of relevant policy issues, especially in the privacy and security area.

This minor is for undergraduate students across the university who are interested in policy issues related to security and privacy, including those who are planning careers in security/privacy as well as those who plan to focus their careers in other areas. The curriculum has been designed to accommodate students from any major as long as they have taken at least one introductory-level college programming course (such as 15-110 or 15-112).

After completing this minor, students will have a good understanding of how to identify potential security and privacy risks and relevant legal and policy issues; a working understanding of security topics such as cryptography, authentication, and Internet security protocols; as well as broad knowledge of several security- and privacy-related areas as they pertain to the design, development, deployment and management of technologies in a variety of practical contexts (e.g., Web, mobile, Internet of Things, social media, crypto currencies).

Admission

Students are not required to apply to enroll in this minor to start the required courses. However, they are encouraged to consult with the minor director on their elective course selection. In addition, students doing the independent study option must get approval from the minor director prior to enrolling in their independent study course. Finally, students must contact the minor director to certify their completion of the minor.

Curriculum

Students are required to take five courses to complete this minor with a minimum of 48 units.

INTRODUCTORY SECURITY COURSE

17-331	Information Security, Privacy, and Policy	12

Students who have taken 15-213 Introduction to Computer Systems may substitute 15-330 Introduction to Computer Security/18-330 Introduction to Computer Security

PRIVACY AND POLICY COURSE

17-333	Privacy Policy, Law, and Technology	9

Students may substitute a 12-unit version of this course: 19-608, 17-333, or 95-818.

PRIVACY ELECTIVES

Complete a minimum of 9 units:		Units
19-534	Usable Privacy and Security	9
19-602	Current Topics In Privacy Seminar	3
17-731	Foundations of Privacy	12

TECHNOLOGY AND POLICY ELECTIVES

Complete a minimum of 9 units:		Units
19-211	Ethics and Policy Issues in Computing	9
19-101	Introduction to Engineering and Public Policy	12
19-402	Telecommunications Technology and Policy for the Internet Age	12
17-562	Law of Computer Technology	9
19-403	Policies of Wireless Systems	12
19-639	Policies of the Internet	12
84-387	Remote Systems and the Cyber Domain in Conflict	9

Crosslisted courses are also allowed.

ADDITIONAL APPROVED ELECTIVE

Students must complete an additional elective of 9 units or more. Students may choose an additional privacy elective or technology policy elective from the list above, or the one of the following security electives:

15-316	Software Foundations of Security and Privacy	9
15-356	Introduction to Cryptography	12
19-303	Cryptocurrencies, Blockchains and Applications	9
19-534	Usable Privacy and Security	9
18-334	Network Security	12
18-335	Secure Software Systems	12
18-435	Foundations of Blockchains	12

Students who have the necessary prerequisites may choose any approved elective from the SCS or ECE security and privacy undergraduate concentration. Check with the minor program director to determine which category of elective each course will fulfill.

Students should be careful to choose electives for which they have appropriate prerequisites. New elective options are expected as more courses are offered. Students may petition to count a course not on this list as an elective. Students should request permission *before* taking a course that is not on this list. Students may not count multiple electives that overlap substantially.

Optional Project: Subject to approval by the minor director, students may optionally count towards one of the elective requirements 9 units of an independent study or research project course in the security or privacy area, under the supervision of a faculty member in any department. In order to receive credit towards the minor, students must submit a brief project proposal to their project advisor and to the minor director and have it approved prior to conducting the project. Depending on the topic of the project, the minor director may approve credits counting towards privacy electives, technology policy electives, security electives, or some combination of these. Students may work individually, with other undergraduates, or as part of project teams with graduate students or research staff. Students involved in a group project must identify specific project components for which they are responsible. In addition, they must submit a final project report to their project advisor and the minor director that includes a literature review and describes the work they completed. Students working on a group project must each submit their own final report, which should also situate their contribution in the context of the larger project. Note, students are expected to work approximately 1 hour per week for each unit of project in which they are enrolled (e.g. 9 units = 9 hours/week of project work).

Double Counting: At most 2 of the courses used to fulfill the minor requirements may be counted towards any other undergraduate major or minor program. This rule does not apply to courses counted for general education requirements.

Materials Science and Engineering Minor

Paige Houser, *Academic Advisor*
Location: Wean Hall 3317

The Designated Minor in Materials Science and Engineering provides the CIT student with a background in the field of Materials Science and Engineering. This minor is open to all CIT students, with the exception of MSE majors. All required and elective courses are taught within the MSE Department.

Course Requirements

Minimum units required for minor 45

The minor requires a minimum of 45 units.

Prerequisites

Students wishing to take the MSE minor must have prerequisite thermodynamics and transport courses. The prerequisite MSE courses may be substituted for by a thermodynamics and transport course in another engineering discipline.

Core Courses (21 units)

27-211	Structure of Materials (Minor Option)	6
27-212	Defects in Materials (Minor Option)	6
27-227	Phase Relations and Diagrams (Minor Option)	9

The laboratories with these courses are not required as core but will be counted as elective units if desired.

Elective Courses (24 units minimum)

The student must select a minimum of 24 units from the following list:

27-100	Engineering the Materials of the Future	12
27-301	Microstructure and Properties I	9
27-570	Polymeric Biomaterials	12
27-477	Introduction to Polymer Science and Engineering	9
27-357	Introduction to Materials Selection	6
27-367	Selection and Performance of Materials	6
27-433	Dielectric, Magnetic, Superconducting Properties of Materials & Related Devices	9
27-432	Electronic and Thermal Properties of Metals, Semiconductors and Related Devices	9
27-421	Processing Design	6
27-445	Structure, Properties and Performance Relationships in Magnetic Materials	9
27-591	Mechanics of Materials	9
27-454	Supervised Reading	Var.
27-533	Principles of Growth and Processing of Semiconductors	6
27-555	Materials Project I	Var.
27-565	Nanostructured Materials	9
27-542	Thin Film Technologies	9
27-592	Solidification Processing	9
42-444	Medical Devices	9

Mechanical Behavior of Materials Minor

Program Contacts

Paige Houser, *Academic Advisor*

Paul S. Steif, *Mechanical Engineering*

An understanding of mechanical behavior is important to both the development of new materials and the selection of appropriate materials for many applications. The mechanical behavior of materials is best investigated and understood by integrating solid mechanics with the microstructural basis of flow and fracture. The purpose of this minor is to allow a formal basis for students to pursue an integrated approach to the mechanical behavior of materials.

Although this minor is open to all CIT students, only students in the departments of Civil Engineering, Materials Science and Engineering, and Mechanical Engineering can take advantage of the double counting permitted for some courses in their department majors. Students in other departments may have difficulty in fulfilling the requirements in four years.

Course Requirements

Minimum units required for minor 51-54

The minor requires six courses: three core courses, two solid mechanics courses, and one materials science course. In satisfying these course requirements, each student must take three out-of-department courses. Each student is required to complete three core courses:

Core Courses:

27-201	Structure of Materials	9
27-591	Mechanics of Materials	9-12
or 27-791	Mechanical Behavior of Materials	
12-212	Statics	9
or 24-261	Mechanics I: 2D Design	

Group A: Materials Science Courses

Each student must take one course from this list of Materials Science courses:

27-202	Defects in Materials [1]	9
27-357	Introduction to Materials Selection [2]	6
27-709	Biomaterials	12

[1] 27-202 cannot be used by MSE students to satisfy the requirements of the minor.

[2] 27-357 cannot be used by MSE students to satisfy the requirements of the minor.

Group B: Solid Mechanics Courses

Each student must take two of the following Solid Mechanics courses:

12-231	Solid Mechanics	9
or 24-262	Mechanics II: 3D Design	
12-635	Structural Analysis	12
or 24-351	Dynamics	

Students should check with the director of the program or their faculty advisor for an up-to-date list of relevant courses that will count towards this minor. For more information, please consult the Undergraduate Course Catalog and the current Schedule of Classes.

College of Fine Arts

Mary Ellen Poole, Dean (CFA 100)

Kristen Kovak, Senior Associate Dean for Academics (CFA 100)
www.cfa.cmu.edu (http://www.cfa.cmu.edu)

Overview

The College of Fine Arts at Carnegie Mellon University was founded in 1905 as the first comprehensive arts learning institution in the United States. For 110 years it has educated outstanding artists, architects, designers, theater artists and musicians who have made important contributions to culture in the United States and the world. The alumni of the College of Fine Arts have shaped the worlds of television, stage, film, and electronic media; are collected in numerous international museums; have composed for and are performing in and conducting major symphony orchestras, choruses and opera companies throughout the world; have built notable buildings, pioneered innovative sustainable design strategies and created interactive software systems; created significant innovations in graphic and industrial design; and are professors and deans in major arts institutions.

The College of Fine Arts concentrates on the education of professionals in the arts in the broader context of Carnegie Mellon University. Beyond their education in their chosen field, through required and elective course work, students are involved with other disciplines within the College of Fine Arts and within the other colleges of Carnegie Mellon University. Further, the College's location in the Oakland District of Pittsburgh with its broad cultural resources (The Carnegie Museum of Art, the Carnegie Museum of Natural History, The Carnegie Library, the University of Pittsburgh, The Hillman Library, the Frick Fine Arts Building, and Phipps Conservatory and Botanical Gardens) places the College of Fine Arts at the center of a premier cultural environment.

The College of Fine Arts has a 9:1 student faculty ratio which provides a rigorous learning environment. It is a highly spirited federation of schools (Architecture, Art, Design, Drama and Music) made up of students and faculty who have an intense need to create and excel. Interacting among the schools, the University and the wider community are research centers such as the Frank-Ratchye Studio for Creative Inquiry, the Center for Building Performance and Diagnostics, Remaking Cities Institute, Center for Iranian Music, and the Center for Arts in Society. The intellectual and artistic life of the College is interwoven with a dense calendar of theater performances, concerts, exhibitions, film and media presentations and lectures by visiting artists, practitioners and scholars.

The College of Fine Arts offers a wide range of professionally oriented majors and minors in each of its schools. In addition, the College offers the Bachelor of Computer Science and Arts (BCSA), jointly with the School of Computer Science, the Bachelor of Humanities and Arts (BHA), jointly with the Dietrich College of Humanities and Social Sciences, the Bachelor of Science and Arts (BSA), jointly with the Mellon College of Science, the Engineering and Arts (EA) additional major, jointly with the College of Engineering, and the Master of Arts Management (MAM) and Master of Entertainment Industry Management (MEIM), jointly with the Heinz College of Public Policy and Management. These are presented only briefly below, but a complete listing of the graduation requirements for these programs may be found in the school descriptions later in this section and elsewhere in this volume.

Schools

School of Architecture

Office: CFA 201

The School of Architecture provides deep immersion in the discipline of architecture, intensified by the broader Carnegie Mellon culture of interdisciplinary innovation and creative inquiry. We define the discipline of architecture as the integrated pursuit of design creativity, historical perspective, social responsibility, technical expertise, and global environmental leadership. Though every School of Architecture student graduates with intensive architecture knowledge, no two graduates leave with the same education. In the twenty-first century, few architecture problems are straightforward. Our graduates excel in the roles architects have performed for centuries—and in new roles catalyzed by the depth and breadth of their education—to create and execute innovative solutions to a huge range of emerging global challenges. The school offers the following degree programs: Bachelor of Architecture (B.Arch), Bachelor of Arts in Architecture, Master of Advanced Architectural Design (MAAD), Master of Architecture (M.Arch), Master of Science and Ph.D. in Architecture–Engineering–Construction Management (MSAECM/PhD-AECM), Master of Science and Ph.D. in Building Performance and Diagnostics (MSBPD/PhD-BPD), Master of Science and Ph.D. in Computational Design (MSCD/PhD-CD), Master of Science in Sustainable Design (MSSD), and Master of Urban Design (MUD).

School of Art

Office: CFA 300

The primary mission of the School of Art is to develop in the individual student the skills, knowledge, and commitment required to work as an artist in society. The four-year undergraduate program leads to a Bachelor of Fine Arts degree in Art. Concentrations within the art major are offered in four areas: 1) Painting, Drawing, Print Media and Photography; 2) Electronic and Time-Based Work; 3) Sculpture, Installation, and Site Work; and 4) Contextual Practice. A Master of Fine Arts degree in Art is also offered.

School of Design

Office: MM 110

The School of Design combines its professional program with a sound education in the liberal arts, leading to careers in many fields of design. It offers the following degrees: Bachelor of Design with concentrations in Communications, Products, and Environments; M. Design in Design for Interactions; M.P.S. in Design for Interactions; M.A. in Design; Ph.D. in Transition Design.

School of Drama

Office: PCA 220

The School of Drama offers a highly focused, world-class theatre education with thorough preparation for sustained careers and innovation in today's widely-varied entertainment industries. The undergraduate programs lead to BFA degrees in Drama, with focuses in Acting, Music Theatre, Directing, Dramaturgy, Design, Production Technology and Management; MFA programs are offered in Scene, Costume, Sound, and Lighting Design; Directing; Dramatic Writing; and Production Technology and Management.

School of Music

Office: HOA 102

The School of Music has as its goal the preparation of musicians for careers in performance, composition, conducting, music education and music technology. The programs provide the opportunity to study with world-class artists utilizing the best aspects of conservatory training in the context of a major research university, combining the educational with the intensely professional. The Bachelor of Fine Arts is offered in Music Composition, Music Performance, and Music and Technology (a joint degree with the School of Computer Science and the Electrical and Computer Engineering Department) with minors in Collaborative Piano, Conducting, Music Education, Music Performance, and Music Technology available. The Master of Music is offered in Composition, Conducting, Performance, Music Education, and Music and Technology (a joint degree with Computer Science and the Electrical and Computer Engineering Department).

Academic Standards

Grading Practices

Grades given to record academic performance in the College of Fine Arts are detailed in the catalog section entitled "Undergraduate Academic Regulations." All courses taught by the schools in the College of Fine Arts follow the standard letter grade system of the university. Responsibility for the grade given to the student rests entirely with the instructor and the school concerned. A permanent grade may not be raised by taking a second examination or evaluation. Students who wish to repeat a course already passed must obtain approval from the Dean of the College. At the time of approval, the Dean will decide in the light of circumstances whether the new grade or the old grade will be the official grade used as the computing factor for honors. Both grades, however, will appear on the official transcript.

Grade Appeals

In the event a student believes an assigned grade is incorrect or not appropriate, the student may follow the university processes outlined in the Word to seek prompt and equitable resolution of the matter. All appeals are initially addressed to the instructor of record. If unresolved, the appeal can be forwarded to the Head of School (or department head if outside of CFA). https://www.cmu.edu/student-affairs/theword/academic/appeal-of-grades-and-academic-actions.html

Monitoring Degree Progress

The College of Fine Arts seeks to support each of our students on their pathway towards graduation. Thus, we review each student's academic performance and progress towards degree at the close of each semester. Academic actions are designed to notify a student of specific academic and graduation requirements, outline goals for completion, and identify avenues of support. Academic actions are opportunities for students to reflect, grow, and get connected with appropriate campus resources to help them succeed.

To stay on track for graduation, each student is expected to complete a minimum of 36* units each semester, have both a semester and cumulative QPA of at least 2.0, and make adequate progress towards their declared degree. *Adequate progress requires that at least 80% of their semester units are passed, that a student registers for their program's expected coursework, and that they have met the minimum grades required to progress in sequential coursework.*

If a student's academic record falls below these standards, they receive an academic action. These actions are assigned based on the most recent semester under review as well as a cumulative review of a student's performance to date. Each program will recommend students for notification and the CFA Academic Advisory Committee will finalize these decisions. The CFA Dean's office will then disseminate the academic action letters directly to the students and their advisors via their CMU email. To best support academic success, a student placed on an academic action is not permitted to overload, undertake independent studies, or study abroad until they return to good standing. (See school/program handbook for additional restrictions and specifications.)

Incomplete grades will be conditionally actioned by the default grades until the student completes the missing coursework. If the student does not complete their missing coursework by the faculty deadline agreed upon, their default grade and action will become permanent.

**Students approved for Part Time Status through the Office of Disability Resources will work with their Program's administration to determine the minimum number of units needed to remain in Good Standing.*

Academic Notifications

A preliminary email from an academic advisor may alert a student of an issue that will impede their degree progress if left unresolved (aka re-taking a general education requirement or falling behind on registering for required courses etc.) If the student meets new actionable criteria in the following semesters, they may be assigned an academic action.

The College of Fine Arts administers academic action letters to help all students stay abreast of their progress towards degree and to ultimately support their path to graduation. If a student falls below the outlined academic standards listed above (earn a minimum 2.0 semester and cumulative QPA and make adequate degree progress), they will receive an academic action letter at the close of that semester. If problems persist, they will receive escalating actions as listed below. <u>However, once a student resumes adequate degree progress and earns a semester and cumulative QPA of at least 2.0, they are returned to Good Academic Standing and will remain in good standing so long as the academic standards are still being met.</u>

Academic Concern

Academic Concern letters notify the student of a concerning academic performance issue(s) and suggests that the student take immediate steps to correct the cause of the difficulty. It is the first academic action administered to students who fall behind one or more of the degree standards. A student will remain on Academic Concern for the length of the next semester (Fall or Spring). Note that Academic Concern is an internal notification and will not appear on a student's academic transcript. If the student does not meet these standards in future semesters, they may be assigned a successive academic action.

Academic Warning

A student will be placed on Academic Warning for <u>continued</u> poor performance, or for <u>continued</u> failure to meet the requirements of their declared degree path. Academic Warning is the second level academic action administered to students who fall behind at least one of the degree standards for two or more semesters. A student will remain on this action for the length of the next semester (Fall or Spring). Again, Academic Warning is an internal notification and will not appear on a student's academic transcript. One or more previous actions are needed to qualify. If the student does not meet these standards in future semesters, they may be assigned a successive academic action.

Academic Suspension

Academic Suspension is a required, temporary leave from the university. It is administered to students who fall behind at least one of the degree standards for three or more semesters. (Two or more academic actions must proceed a suspension). An Academic Suspension is intended to allow the student time to address any issues impeding or affecting their performance in order to progress towards meeting the academic standards of their declared degree path. The student is required to temporarily withdraw from the university for a specific period as defined in their suspension letter.

The College of Fine Arts remains committed to students during these periods of temporary leave and continues to connect them to College and University level supports while they are away. Return from suspension is subject to the conditions specified in the suspension letter and approval of the CFA Dean's office. Details concerning associated restrictions can be found at: *https://www.cmu.edu/policies/student-and-student-life/suspension-required-withdrawal-policy.html*).

Final Academic Warning

Following a Suspension, students will be placed on Final Academic Warning during their initial semester of return.

Academic Drop

An Academic Drop is the final academic notification and is only administered after a substantial pattern of academic difficulty. Four or more semesters below standards, including a Suspension, are needed prior to an Academic Drop.

This action terminates the student's enrollment in their current School/Program but is not intended to prejudice admission to another academic program within Carnegie Mellon University, or to another institution. If a student has earned a cumulative grade point average of at least a 2.0, they may still apply for internal transfer within CMU– noting that the student must successfully transfer prior to resuming study at Carnegie Mellon.

Appeal of Academic Actions

Students have the right to appeal Academic Action decisions to the CFA Dean. All appeals must be received in writing by the deadline printed in the academic standing notification (within 10 days of the dated letter). If a student's initial appeal is denied they may choose to further their appeal to the Provost's Office in writing by the deadline printed in the appeal response (within 5 days of the dated letter). Additional information about appealing an academic action decision is found in The Word: Student Handbook (https://www.cmu.edu/student-affairs/theword/academic/appeal-of-grades-and-academic-actions.html).

Dean's Honor List

Each semester the College of Fine Arts recognizes those students who have attained outstanding semester quality point averages by naming them to the Dean's List. To be eligible, students must complete at least 36 factorable units and have no conditional, missing or failing grades in core classes at the time when final semester grades are recorded. The top 35% of eligible students in each of the College of Fine Arts schools are named to the Dean's List.

Graduation Requirements

Because of the special nature of work in the College of Fine Arts, the first year in all schools should be considered probationary, a period in which a student and faculty can evaluate professional promise in terms of the college's standards. Graduation from the College of Fine Arts follows the general university guidelines. As part of a student's qualification for an undergraduate degree, the equivalent of two terms of full-time work must be pursued under the direction of faculty members in the college during the period immediately prior to the degree award. Courses completed at other institutions will not be acceptable as terminal credit for a degree. Exceptions to this stipulation can be recommended by a school faculty in unusual cases, but the concurrence of the College Council is necessary before final approval of an exception can be given.

To be eligible to graduate, undergraduate students must complete all course requirements for their program with a cumulative Quality Point Average of at least 2.0 for all courses taken. For undergraduate students who enrolled at Carnegie Mellon as freshmen and whose freshman grades cause the cumulative QPA to fall below 2.0, this requirement is modified to be a cumulative QPA of at least 2.0 for all courses taken after the freshman year. Note, however, the cumulative QPA that appears on the student's final transcript will be calculated based on all grades in all courses taken, including freshman year. Some programs may have additional QPA requirements in order to graduate.

Other graduation requirements in the College of Fine Arts are described in the curriculum of each school. Further questions about specific course requirements and the total number of units required should be directed to the respective school advisors.

Other Regulations Affecting Student Status

Schedule Changes

Courses may be added or dropped within the times stated in the college calendar. No courses may be added or dropped after the stated deadline dates except with the approval of the student's School Head and the Dean of the College. (See Undergraduate Academic Regulations (p. 25) for Add/Drop procedures.)

Withdrawal/Leave of Absence

Please refer to the Student Leave Policy.

Transfer Students

Undergraduate students seeking transfer within or to any school of the College of Fine Arts must file an application with the School and proceed with the established transfer application procedure, audition, portfolio review or ASAT requirements. Admission may dictate freshman status regardless of the student's prior college experience.

Materials

The college does not furnish students with any drawing materials, make-up materials, textbooks, or other expendable equipment except those in courses in which materials fees are charged to cover specific costs.

Retention of Students' Work

The college reserves the right to retain indefinite documentation of any student work the faculty may select. All work not retained by the faculty must be claimed at the time specified by the schools concerned. The college assumes no liability for student materials in its custody.

Student Defined Majors

The Student Defined Major program in the College of Fine Arts is designed for the exceptional student, whose area of artistic interest lies outside of any pre-existing program at the University. Student Defined Majors are expected to propose a comprehensive plan of study that combines all of their coursework into a singular focus for their research and artistic practice. To create a successful proposal, the student must engage in additional career and preparatory research outside of their normal coursework. Designing the independent degree program typically takes six months to one year to complete.

Students interested in pursuing this unique degree path should meet with their academic advisors to discuss feasibility. They will then work with the CFA Senior Associate Dean of Interdisciplinary Initiatives to ensure that their proposed coursework meets the rigorous requirements of a Carnegie Mellon degree. They will need approval from their academic advisor, faculty mentor(s), relevant Head(s) of School, (Senior) Associate Dean(s), and the Vice Provost for Education. If the proposal is approved and the student has successfully met the requirements of the new major, the degree conferred at graduation will be a *Bachelor of Arts* with a *Student Defined Major: *approved title**. The CFA Office of the Dean, in consultation with the academic advisor, will determine final certification of the degree. Note that all academic actions and CFA policies still apply to Student Defined Majors.

To apply for a Student Defined Major in the College of Fine Arts, one:

1. Must be a student in good standing at the University.
2. Must have successfully completed at least one semester of study and have at least two semesters left prior to their intended date of graduation.
3. Must have a cumulative QPA of 2.75 or better. (A student whose QPA is under 2.75 may still submit a proposal, but is strongly advised against it. If the proposal is accepted by the CFA Senior Associate Dean of Interdisciplinary Initiatives, the student must apply for transitional status for the following semester and will have only one semester to improve his or her QPA to the 2.75 minimum. If the student is not successful in raising the QPA to the 2.75 minimum they will not be permitted to continue with the Student Defined Major. They must either be re-admitted back into their old program or seek admittance into another department or college.)
4. Must have a faculty mentor in the College of Fine Arts who has agreed to mentor the student through the completion of the degree. This mentor should be from the school where the student is taking the majority of their courses, and be approved by the CFA Senior Associate Dean of Interdisciplinary Initiatives. If a student wishes to work extensively across colleges, they will need a faculty advisor(s) from their additional area(s) of concentration as well as approval from an Associate Dean of each college involved.
5. Must successfully complete the proposal process and submit all approved documentation with necessary signatures to the CFA Office of the Dean, CFA 100, by May 1 to be effective in the fall semester, and by October 1 to be effective in the spring semester. (Proposals that come in after these dates will be considered, but may not be able to be processed until the following semester.)

Student Organizations

Professional and honorary societies for students in the College of Fine Arts are the American Institute of Architects, Architecture Peer Mentors, Architecture Student Advisory Council, National Organization of Minority Architecture Students, Freedom by Design, Alpha Rho Chi Medal, AIA Medal of Excellence, the Design League, American Institute of Graphic Arts (AIGA), Industrial Designers Society of America (IDSA), United States Institute for Theatre Technology (USITT), Phi Mu Alpha Sinfonia (music fraternity for men), Sigma Alpha Iota (music sorority for women), Pi Kappa Lambda (honorary for students in music) and the Music Educators' National Conference.

BXA Intercollege Degree Programs

BACHELOR OF COMPUTER SCIENCE AND ARTS (BCSA), BACHELOR OF HUMANITIES AND ARTS (BHA), BACHELOR OF SCIENCE AND ARTS (BSA), ENGINEERING AND ARTS (EA) ADDITIONAL MAJOR

M. Stephanie Murray, *Director & Academic Advisor*
Location: HOA 211

www.cmu.edu/interdisciplinary (http://www.cmu.edu/interdisciplinary/)

The **Bachelor of Computer Science and Arts** (BCSA) is a four-year intercollege degree-granting program designed for students interested in pursuing fields that comprehensively meld technology and the arts through courses offered in the College of Fine Arts and the School of Computer Science. It combines general education requirements, a concentration of courses in the College of Fine Arts, a concentration of courses in the School of Computer Science, and free electives.

The **Bachelor of Humanities and Arts** (BHA) is a four-year intercollege degree-granting program designed for students interested in blending studies in the College of Fine Arts and the Dietrich College of Humanities and Social Sciences. The BHA degree combines a general education requirement, a concentration of courses in the College of Fine Arts, a concentration of courses in the Dietrich College of Humanities and Social Sciences, and free electives.

The **Bachelor of Science and Arts** (BSA) is a four-year intercollege degree-granting program designed for students interested in combining studies in the College of Fine Arts and the Mellon College of Science. It combines general education requirements, a concentration of courses in the College of Fine Arts, a concentration of courses in the Mellon College of Science, and free electives.

The **Engineering and Arts** (EA) additional major is an interdisciplinary program designed for College of Engineering students interested in developing their skills and interests in an area of the College of Fine Arts while retaining their full engineering curriculum and licensure. It combines a BXA course requirement and a concentration of courses in the College of Fine Arts with a students primary engineering major.

Please refer to Interdisciplinary Programs (p. 894) in this catalog for details.

The Master of Arts Management Program

Location: 1115 Hamburg Hall

The search for both increased support and larger audiences has intensified over the last decade and now, more than ever, arts organizations seek skilled managers. To meet this need, the College of Fine Arts and the Heinz College's School of Public Policy and Management jointly developed the Master of Arts Management (MAM) Program to provide strong leadership in theater companies, dance companies, orchestras, opera companies, museums, galleries and arts policy organizations. In addition to the traditional two-year graduate degree structure, the Master of Arts Management Program provides undergraduate students the opportunity to complete the Bachelor of Fine Arts and Master of Arts Management degrees within a period of five years through the Heinz College's Accelerated Masters Program (AMP). MAM Program alumni can be found managing music and arts service organizations; marketing orchestras, theaters and dance companies; fund-raising for museums, opera companies, ballet companies and public television stations; and managing the finances of university arts departments and private businesses working in the arts and entertainment industry.

College of Fine Arts Interdisciplinary Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

62-002 CFA Elective

Intermittent: 9 units
TBA

62-104 Design Ethics & Social Justice in Architecture

Fall and Spring: 3 units
This course is aimed at first year architecture students as an introduction to social justice and design ethics. The course will explore how architecture relates to the human experience, human labor, and human rights; how the economic, political, and cultural contexts in which architects work contribute to issues of inequity; and what responsibilities architects and designers have to assure a greater sense of social justice for all. We will start by examining the traditional norms for the "standard" human body in design. Then will explore the meaning of identity (including race, class, gender, ethnicity), economic class and privilege. We will continue by exploring social justice, activism, climate change, colonialism and historically racist urban practices. Throughout the course, we will discuss how architecture is embedded in these issues and how architects might address these issues in current and future practice, both as citizens and as designers. This course includes lectures, weekly reading responses, and small group discussions. Class attendance and participation is required.

62-106 Architecture and the Arts

Fall: 9 units
This interdisciplinary course explores the entangled relationship between architecture and the arts, and their struggle between autonomy and engagement. It will be structured around a series of themes, drawings, and writings that reveal architecture's constantly changing involvement with art, culture, society, and related disciplines The course functions both an introduction to Architecture as Art for a general audience, as well as a critical introduction to architectural thinking and theory for architecture majors. The course will include slide lectures, readings, reading reports, discussions, and a series of research exercises to engage architecture and art more critically, and an exam. We'll examine the common roots, disparate characters, and inter-twined histories of architecture and the arts. We'll investigate not just buildings and art works, but ideas, drawings, images and other representations involved in the construction and reception of architecture that often relate closely to the arts. We'll look at shared terms like composition, rhythm, studio, and form. We'll define architecture in relation to categories such as fine and applied arts, high and low arts, visual and performing arts, and relate these to broad categories such as design, visual culture, and the liberal arts. We'll ask "why" we make architecture and art, rather than "how," and discuss how the human need for expression and meaning can augment the technical and constructed value of mere making or building. We'll debate how the discipline of architecture has been, and can continue to be framed as a fine art, but also act as a service profession, a political tool, a technical expertise, a research endeavor, or as a mode of cultural discourse.

62-122 Digital Media I

Fall: 6 units
This course will engage in an overview of foundational workflows in digital media regarding two-dimensional representation techniques for spatial design processes. The course is divided into two topics with one assignment each: Technical Drawing and 2D Graphics. Students are required to submit work at the end of each class, in addition to self-guided work outside of class times: satisfactory completions of the two assignments, specific Lynda tutorials, final project, and final portfolio are required for the successful completion of the course. Through these deliverables, the course will inquire issues of 2D representation as it pertains to the effective communication of technical and conceptual information in spatial design processes. With digital media, designers now have an arsenal of tools that can subvert and augment traditional means of representation with exponentially greater fidelity and efficiency. Students will have an opportunity to practice these values and favor hybrid approaches that strive to blur the boundaries of analog and digital media, so as to learn how to be versatile in leveraging all forms of media for the design task at hand. Students are required to bring their own laptop computers with AutoCAD, Photoshop, Illustrator, and InDesign installed.

62-123 Digital Media II

Spring: 6 units
This is the second course in a two-course sequence that introduces students to a broad range of architectural drawing techniques and practices that document, communicate, and generate design possibilities. The course situates modes of representation within a rich disciplinary tradition, as well as within adjacent fields of discourse on visual culture and epistemology. This second instantiation expands the foundational skills established in 62-122 by surveying select, contemporary modes of digital production and communication especially as situated between design disciplines and adjacent practices in the sciences, the animation and gaming industries, digital forensics and archaeology, artificial intelligence and other modes of cultural production. The course also challenges students to establish a visual agenda of their by referencing and critiquing chosen practices and styles within contemporary architectural media.
Prerequisite: 62-122

62-125 Drawing I

Fall: 6 units
62-125 is an introductory course in free-hand architectural drawing. Its central learning objective is building a capacity for visualizing three-dimensional space through freehand drawing. A parallel objective is fostering visual literacy: the ability to use line and tonal values to represent architectural space. Topics covered are contour drawing, freehand perspective, axonometric projection, and tonal drawing in charcoal. The course concludes with a final project conducted jointly with 48-100, first-year architectural design.

62-126 Drawing II

Spring: 6 units
The central learning objective of Drawing II is building a capacity for visualizing three-dimensional space through freehand drawing. It has two secondary objectives: using line, tone and color to represent architectural space and architectural proposals. The course has four parts 1) free-hand and constructed perspective, 2) shade and shadow and chiaroscuro drawing in charcoal and colored pencil, 3) color drawing in pastel. 4) a final project combining freehand drawing, color work in Photoshop and a 3D digital model. Prerequisite: 62-125 or permission of the instructor.
Prerequisite: 62-125

62-141 Black and White Photography I

Fall and Spring: 10 units
This course will teach you the basic craft of photography from exposure of the negative through darkroom developing and printing to print finishing and presentation. Content includes student presentations, class discussions, shooting assignments, darkroom sessions and class critiques. We will concentrate not only on the technical aspects of photography, but also the aesthetics of seeing with a camera. The course concentrates on photography as a fine art and #8212; what is unique to it and the concerns that are shared with other visual arts, such as composition, tonal values, etc. and aims to equip students with an understanding of the formal issues and the expressive potentials of the medium. Use your own 35 mm camera, or borrow one from us for the semester. Students are responsible for the cost of photo paper and film, and a lab fee is charged for the course.

62-142 Digital Photography I

Fall and Spring: 10 units
This course explores digital photography and digital printing methods. By semester's end students will have knowledge of contemporary trends in photography, construction (and deconstruction) of photographic meaning, aesthetic choices, and the use of color. Students will learn how digital cameras work, proper digital workflow, RAW file handling, color management and Adobe Photoshop. Through the combination of the practical and theoretical, students will better define their individual voices as photographers. No prerequisites.

62-150 IDeATe Portal: Introduction to Media Synthesis and Analysis

Fall: 10 units
Technologists, artists, and designers are engaging in new, interdisciplinary modes to consume, create, and reuse media. To do this, they thoughtfully collaborate and critically reflect on media creation, distribution, participation, interaction, and how media affects the audience. In this course, students will challenge themselves to work in these new modal contexts by thinking critically in a genre of exploration. They will formulate the intent of their creative work, articulate relationships to art/design practice and theory, and respond insightfully to creative, media-rich outcomes. The class will introduce core concepts through foundational texts, in-class exercises, collaborative projects, and group critique. Through hands-on media exploration, students will ground concepts such as embodiment, emergence, composition, participatory interfaces, and mediated experiences. Section A will be an Introduction to Textile Media. Section B will be an Introduction to Mediascapes: 2D to 3D Spatial Environments. Section C will be Life in the Digital Factory: Spatial Storytelling about Computational Landscapes.

Course Website: https://ideate.cmu.edu/courses/portal-and-section-details.html

62-207 IDeATe: Variational Geometry I

Fall: 6 units
This course will introduce concepts and strategies for the modeling and development of complex computational geometry for 3D printing purposes and introduce algorithmic thinking using the Rhinoceros McNeel platform and Grasshopper plugin. This course is intended for students with no or little 3-D modeling skills to advance their abilities in modeling, digital prototyping and visual communication.

Course Website: http://ideate.cmu.edu/about-ideate/departments/college-fine-arts/ideate-variational-geometry-i/

62-225 Generative Modeling

Fall and Spring: 9 units
This course introduces students to the fundamentals of generative modeling using computer aided design as practiced in the field of architecture. Core competencies will be developed through modeling projects and software intensive labs, while a broader critical framework for conceiving of contemporary and historical parametric practices will be encouraged through periodic lectures. Emphasis will be placed on careful consideration of digital mediums and developing a sense of craft related to digital modeling in the hope that students will become conscientious makers and consumers of digital content. Students will be encourage to understand and apply algorithmic problem solving to the many design constraints encountered in architecture. The course will explore the relationship of parametric workflows to design thinking and will situate contemporary trends in a broader framework of computational design. The course will also forefront complex form-making as a response to bio-mimicry, systems thinking, and mass-customization. Rather than positioning parametric modeling as a disruption of historical architectural design process, the course will encourage students to consider how new tools might augment the discipline's historical commitments to orthographic projection, perspectival drawing, and physical modeling.

62-239 Reading Pictures, Writing Photography

Intermittent: 9 units
Through photography's history, writers have sought to identify what is special about photography, the medium's essential characteristics, and what happens when photographs make something visible. In this course students will engage critically with photographs and photography through classic and contemporary texts on photography, and by producing their own writing. Students will become familiar with significant photographers and key issues raised around photography and develop their own critical and authorial voices. Readings include pieces by Roland Barthes, Walter Benjamin, Susan Sontag, Hito Steyerl, Rebecca Solnit, Teju Cole, and many others.

Course Website: http://cfaphoto.cfa.cmu.edu/classesf17.html

62-241 Black and White Photography II

Fall and Spring: 10 units
Black and White Photography II continues developing your technical skills in analog photography by introducing medium and large format cameras and prints. Large format view cameras remain the state of the art in control and quality in both film and digital photography. These cameras as well as unusual panoramic and pinhole cameras will be supplied. This course emphasizes aesthetic development and personal artistic growth through individual tutorials and group critiques, and will help to build professional level photography skills. Additional topics include digital printing and negative scanning, advanced monotone printing methods, and a focus on exhibition and folio presentation. Students are responsible for the cost of photo paper and film, and a lab fee is charged for the course.
Prerequisites: 62-141 or 60-141

62-245 Portrait Photography

Intermittent: 10 units
Portraiture maintains a unique standing in photography for its direct and collaborative relationship between an individual and a photographer. This course will examine this relationship and the larger contexts which provide the conceptual framework for deriving meaning and understanding from an image of another person. We will study the theoretical and practical aspects of portrait photography in both studio and environmental settings, providing students with an understanding of the genre by developing both technical and conceptual skill sets. Students will utilize analog and digital equipment, learn studio lighting techniques, develop approaches to working with natural light, and explore methods of printing and presentation. Students will gain knowledge in the development of portraiture through the work of notable figures in the medium's history and contemporary field, including August Sander, Dorothea Lange, Walker Evans, Dawoud Bey, Milton Rogovin, Rineke Dijkstra, Zoe Strauss, Susan Lipper, Justine Kurland, Stefan Ruiz, Larry Sultan, Carrie Mae Weems, Roy DeCarava and Alec Soth. Class discussions, readings and critiques will provide an outline for completing both single and serial image assignments.

62-247 Introduction to Hot Glass I

Fall and Spring: 3 units
In this introductory class, learn to gather clear molten glass from the furnace and then shape it into various forms, from paperweights to simple blown shapes, such as cups and bowls. Instruction focuses on a team approach to glassblowing, with an emphasis on safety, proper tool use, basic techniques, and materials. You'll never drink from a glass again without appreciating the energy and detail that went into making it! Little to no hot shop experience is required. You may also wish to take this class a second time in order to continue to develop and refine basic skills before moving on to Hot Glass 2. Each time you take it, your skill level, confidence, and passion for glass will grow. Class tuition includes 2 hours of open-studio time to be used during the 8-week course period. This will help you become familiar with the studio itself and learn the process of studio rental beyond class hours. Registration for Pittsburgh Glass Center classes can only be done on or after your scheduled registration day. Spaces are limited. Registration is done on a first come, first served basis. Please email Stefanie McGowan (stefanim@andrew.cmu.edu) for more information and to register. Course fee is $325. Not eligible for PCHE Cross Registration. Course taught at the Pittsburgh Glass Center. Courses at the Pittsburgh Glass Center will run from September 24, 2024 to November 24, 2024.

Course Website: https://www.pittsburghglasscenter.org/

62-275 Fundamentals of Computational Design

Fall and Spring: 9 units
As analog mechanisms; as metaphors; as bodily extensions or prosthetics; as material systems; as building envelopes; as partners or slaves? of humans. This course takes computers outside the box and outs a journey of discovery revealing computation as the connective tissue encompassing multiple facets of architectural practice and experience. Addressing conceptual and practical aspects of the relationship between computation and design, the course explores the fundamentals of generative and rule-based systems for designing and making, simulation, and responsiveness, along with basic approaches to creative data processing, representation, and realization. The course offers a holistic view of computation, exploring the different roles computing plays in the design of our built environment. Organized in two-week modules, the course explores six themes, each combining historical insight, architectural examples, and hands-on design exploration.
Prerequisite: 48-100

62-279 Photography and the Ineffable

Fall and Spring: 10 units
This course explores the relationship between photography and the indescribable, intangible, and hard-to-see. From the spiritual, to the sublime, to the abstract; we will review different frameworks for thinking about the ineffable and how it relates to photographic work. Students will explore these themes through weekly presentations, discussions, assignments, writing workshops, and critiques. We'll look at artists who think critically about photographic representation and investigate a heightened sensorial interpretation of the world. This class will encourage experimental methods and approaches to photography.

62-314 The Art of Personal Finance

Fall and Spring: 6 units
Money is an inevitable part of our everyday lives. Managing the money we earn and living within our means is essential to ensure that we have the freedom to do what we want to do with our lives. However, even if we successfully eliminate debt and save for the future, true financial freedom will not exist unless we have a plan to guide us on our way. In this course, students will create a simple one-page financial plan that they can use to guide them through their next several years as they cultivate the skills that will ensure their artistic success. Additionally, they will develop the tools needed to support the execution of the plan and create a sourcebook of information they can refer to in the future as their lives (and their financial plans) change.

62-315 Shaping Environments: Experiments in Geometry and (Waste)Matter

Fall
Shaping Environments is a design-research seminar that explores alternative material formations beyond our current petrochemical reality. Using digital environments and computational tools, such as photogrammetry, depth-map texture modeling, AI workflows, and 3D printing, we will experiment with shaping new hybrid material systems. Using resources, such as food and/or construction waste, our goal is to propose new material paradigms that embrace ecological thinking and environmental stewardship through physical prototyping.

62-343 Professional Practices in Photography

Fall and Spring: 10 units
This studio course will introduce students to the working methods of professional photographers and artists. For the first half of the course, students will develop a substantial body of visual work. They will then use that work in the second half of the semester to produce portfolios across a variety of media (digital, print, web, exhibition, etc.). Throughout the process they will develop skills in constructing and completing projects, cultivate their personal vision and aesthetic tastes, explore methods of disseminating their work to larger audiences, establish time management and planning around long form projects, and acquire an understanding of the marketing, outreach and community building necessary for working artists to build and sustain a career.
Prerequisites: 60-142 or 62-142 or 62-141 or 60-141

62-347 Hot Glass II

Fall and Spring: 3 units
Enroll in Hot II and build on your existing skill set and expand your creative potential. Refine and diverge from the standard cup and bowl shape in the first few weeks before moving on to more complex forms. Explore basic color application methods and learn how to troubleshoot common problems. It is recommended that all students take this class a second time in order to continue to develop and refine basic skills before moving on to Advanced Hot Glass. Hot I, 24 hours of hot shop experience, or instructor permission is required. Registration for Pittsburgh Glass Center classes can only be done on or after your scheduled registration day. Spaces are limited. Registration is done on a first come, first served basis. Please email Stefanie McGowan (stefanim@andrew.cmu.edu) for more information and to register. Course fee is $325. Not eligible for PCHE Cross Registration. Course taught at the Pittsburgh Glass Center. Courses at the Pittsburgh Glass Center will run from September 24, 2024 to November 24, 2024.
Prerequisite: 62-247

Course Website: https://www.pittsburghglasscenter.org

62-360 Photographers and Photography Since World War II

Spring: 9 units
Invented in 1839, photography was a form of visual expression that immediately attracted a large public following. Starting around 1900, photography was practiced with two dominant strands. One of these firmly believed in the power of photographs to provide a window on the world, and was led by Lewis Hine, whose documentary photographs for the National Child Labor Committee helped to ameliorate living and working conditions for thousands of immigrant children. The other strand adhered to the philosophy of Alfred Stieglitz who adamantly affirmed that photographs were first and foremost reflections of the soul and were art objects, equal to painting, drawing and sculpture. These two schools of thought guided photographers throughout the twentieth century. This course explores in depth the tremendous range of photographic expression since World War II and examines in particular the contributions of significant image-makers such as Helen Levitt, W. Eugene Smith, Robert Frank, Diane Arbus, Garry Winogrand, Charles "Teenie" Harris, Cindy Sherman, Carrie Mae Weems, Nan Goldin, James Nachtwey, and many others. Classes include a slide lecture, student presentation, and video segments that introduce a focused selection of images by major photographers in an attempt to understand their intentions, styles, and influences.

62-362 IDeATe: Electronic Logics && Creative Practice

Intermittent: 12 units
Electronic Logics and amp; and amp; Creative Practice investigates the fundamentals of electronic computation as metaphors for art and interaction. Students explore technology through a creative lens, as conceptual and physical material to be manipulated and synthesized, by examining the basis of digital computation alongside contemporary and new media art practices. There are three main units: Gates (the logical building blocks of computers), Flow (ways in which signals "flow" through physical and electronic systems), and Arrows (the stacked layers of indirection used in modern computer systems). These major themes are addressed through lecture, readings, and the creation of individual and collaborative works. Throughout the semester students complete a series of quick thematic exercises and three larger-scale projects; these works are reviewed through meetings, group critique, and documentation. Our toolbox includes 7400-series logic chips, the Arduino electronics platform, software, wood, laser cut acrylic, found objects, props, projections, and glue. We address technical engineering subjects (e.g. Karnaugh maps) alongside art and performance theory. Students deepen conceptual skills while increasing the scale and ambition of creative output. The course culminates in an end-of-semester showcase where students publicly exhibit their work.

62-371 Photography, The First 100 Years, 1839-1939

Fall: 9 units
Photography was announced to the world almost simultaneously in 1839, first in France and then a few months later in England. Accurate "likenesses" of people were available to the masses, and soon reproducible images of faraway places were intriguing to all. This course will explore the earliest image-makers Daguerre and Fox Talbot, the Civil War photographs organized by Mathew Brady, the introduction in 1888 of the Kodak by George Eastman, the critically important social documentary photography of Jacob Riis and his successor, Lewis Hine, the Photo-Secession of Alfred Stieglitz, the Harlem Renaissance of James VanDerZee, the precisionist f64 photographers Ansel Adams, Imogen Cunningham, and Edward Weston, and other important photographers who came before World War II. The class will be introduced to 19th century processes, such as the daguerreotype, tintype, and ambrotype, as well as albumen prints, cyanotypes, and more.

62-450 Introduction to Flameworking

Fall and Spring: 3 units
Learn flame shop essentials and a variety of creative techniques while working with a solid rod of glass. Using a propane/oxygen torch, students will learn to melt and manipulate glass into little treasures, such as beads, pendants, marbles, chains, and sculptures. Over the course of 8 weeks, learn color application, hand control, and annealing. The instructor will also provide one-on-one troubleshooting. Class tuition includes 2 hours of open-studio time to be used during the 8-week course period. This will help you become familiar with the studio itself and learn the process of studio rental beyond class hours. Registration for Pittsburgh Glass Center classes can only be done on or after your scheduled registration day. Spaces are limited. Registration is done on a first come, first served basis. Please email Stefanie McGowan (stefanim@andrew.cmu.edu) for more information and to register. Course fee is $200. Not eligible for PCHE Cross Registration. Course taught at the Pittsburgh Glass Center. Courses at the Pittsburgh Glass Center will run from September 24, 2024 to November 24, 2024.

Course Website: https://www.pittsburghglasscenter.org

62-459 Intro to Stained Glass

Fall and Spring: 3 units
Explore the possibilities of colorful stained glass. In this introductory course, you will learn the basics for working with flat glass; cutting, grinding, foiling, and soldering. You will explore the famous Tiffany Method of construction and work with provided patterns to create a beautiful stained-glass pane ready for display! This class is designed for beginners and is a pre-requisite for Intermediate and Advanced Stained Glass. Registration for Pittsburgh Glass Center classes can only be done on or after your scheduled registration day. Spaces are limited. Registration is done on a first come, first served basis. Please email Stefanie McGowan (stefanim@andrew.cmu.edu) for more information and to register. Course fee is $250. Not eligible for PCHE Cross Registration. Course taught at the Pittsburgh Glass Center. Courses at the Pittsburgh Glass Center will run from September 24, 2024 to November 24, 2024.

Course Website: https://www.pittsburghglasscenter.org

62-478 IDeATe: digiTOOL

Fall and Spring: 9 units
This course serves as an introduction to the fundamental concepts, processes, and procedures to utilize digital and traditional equipment within the IDeATe facilities in Hunt Library. After completion, participating students should leave with a thorough understanding of 3D modeling, 3D printing, laser cutting, engraving, and basic finishing techniques. Students will learn how to operate in a safe, responsible, and efficient manner. This comprehension and experience proves useful for all creative disciplines, and participants are certified for future fabrication equipment access.

Minors Offered by the College of Fine Arts

The College of Fine Arts offers minors in Architecture, Art, Design, Drama, and Music to students from other colleges at Carnegie Mellon University. These minors allow students at Carnegie Mellon to take courses and develop a direction for electives in any of the five schools in CFA. Students in the College of Fine Arts may also earn minors outside of their major within other schools in the College. They may also study any of the minors offered by the other colleges to the University at large, thus taking advantage of the broad educational opportunities available at Carnegie Mellon University.

Minors Offered by the College of Fine Arts:

- Architectural Design Fabrication (available only to B. Arch candidates)
- Architectural Representation and Visualization (available also to B. Arch candidates)
- Architectural Technology
- Architecture
- Architecture History (available also to B. Arch candidates)
- Art
- Building Science (available only to B. Arch candidates)
- Collaborative Piano (available only to Piano majors in the School of Music)
- Conducting (available only to students in the School of Music)
- Design
- Drama
- History of the Arts
- Media Design (IDeATe)
- Music
- Music Education (available only to students in the School of Music)
- Music Technology
- Music Theory
- Musicology
- Photography
- Sonic Arts (IDeATe)

Guidelines for students are: 1) except where so designated, CFA students are not eligible to earn a minor in their own school; students from outside CFA may earn a minor in any school in CFA; 2) faculty advisors in the student's home school (in consultation with the academic officer of the other unit involved) will advise students as to the structuring of the courses in each minor; 3) a minor is not to be considered an overload; rather, through the assistance of faculty advisors it should be integrated into a student's overall units required for graduation; 4) the advisors will also monitor the student's development in these minors and keep records in their files which indicate the fulfillment of the course requirements in the minors, as well as in the majors in the student's own school. Courses listed as possible for the minors may be available, but not all courses are offered every semester. Students should consult with their advisors.

Students interested in earning a minor in any of the CFA schools should contact: Architecture: Heather Workinger; Art: Keni Jefferson; Design: Jamie Kosnosky; Drama: Valeria McCrary; Music: Sharon Johnston; IDeATe: Kelly Delaney.

Architecture Minors

For the most up-to-date list of architecture-related minors, see: https://soa.cmu.edu/minors (https://soa.cmu.edu/minors/).

Minor in Architecture

Available to non-architecture majors only (minimum 54 units total)

This sequence is for candidates who intend to develop intellectual links to the architectural profession. The scope of courses offered includes a full spectrum of professional issues in architecture.

Prerequisite Courses — 9 units

79-104	Global Histories or course 62-110 or 62-106	9

Required Courses — 19-24 units

48-100	Architecture Design Studio: POIESIS STUDIO 1	12
or 48-095	Spatial Concepts for Non-Architecture Majors	
48-240	History of World Architecture, I	9

Elective Courses* — 26-31 units

62-125	Drawing I	6
62-126	Drawing II	6
62-122	Digital Media I	6
62-123	Digital Media II	6
48-215	Materials & Assembly	9
48-324	Structural Design 1: Form and Forces	3
48-380	Constructing Value(s): Economies of Design	6
48-381	Issues of Practice	6
48-383	Ethics and Decision Making in Architecture	6
48-xxx	Architecture History (Pre-Approval of coursework required)	9
48-xxx	Architecture Elective (Pre-Approval of coursework required)	9

Minimum Units: 54

*Students should consult the Architecture advisor regarding elective choices.

Minor in Architecture History

Available to both architecture majors (63 total units total) and non-architecture majors (54 total units total)

This sequence is intended for candidates interested in the history of architecture in its many manifestations, including high style and vernacular buildings, western and non-western traditions, built and theoretical works, and rural to urban contexts. Non-architecture majors are required to take 54 units of architectural history. Architecture majors wishing to minor in Architectural History must fulfill the three core required courses in architectural history, plus four additional architectural history electives, for a total of 63 units. Students wishing to pursue the minor should meet with the Architecture advisor to determine if a course is eligible.

Required Courses — 18 units

48-240	History of World Architecture, I	9
48-241	History of Modern Architecture	9

Selective Courses — 36 units/45 units

Students should consult the Architecture advisor regarding elective choices.

Minimum Units: 54 (non-architecture majors)
Minimum Units: 63 (architecture majors)

Minor in Architectural Representation and Visualization

Available to both architecture majors (63 total units total) and non-architecture majors (54 total units total)

The Minor in Architectural Representation and Media is intended for those students that want to deepen their knowledge in architectural representation and media and for those who are interested in gaining advanced placement (AMP) in the M.S. programs offered by the School in the areas of Computational Design (MSCD). It is earned by completing the four required media courses and then an additional three elective courses in these areas. Architecture majors wishing to pursue a Minor in Architectural Representation and Visualization must complete the required 33 units and at least an additional 30 units to fulfill the minor for a total of 63 units.

Required Courses 24 units

62-122	Digital Media I	6
62-123	Digital Media II	6
62-125	Drawing I	6
62-126	Drawing II	6

Selective Courses 30-39 units

48-568	Advanced CAD, BIM, and 3D Visualization	9
48-724	Scripting and Parametric Design	10
48-3xx	Architectural Drawing Elective (Pre-Approval of coursework required)	9
48-xxx	Architectural Representation/Visualization Elective: (Pre-Approval of coursework required)	9
48-xxx	Architectural Representation/Visualization Elective: (Pre-Approval of coursework required)	9

Minimum Units: 54 (non-architecture majors)

Minimum Units: 63 (architecture majors)

Minor in Architectural Technology

Available to non-architecture majors only (minimum 54 units total)

This sequence is for candidates who intend to develop intellectual links to the technical aspects of the profession.

Prerequisite Courses 22 units

33-141	Physics I for Engineering Students	12
21-120	Differential and Integral Calculus	10

Selective Courses 32 units

48-116	Introduction to Building Performance	3
48-215	Materials & Assembly	9
48-324	Structural Design 1: Form and Forces	3
48-315	Environmental Systems: Climate & Energy in Buildings	9
48-432	Environment II: Design Integration of Active Building Systems	9
48-752	Zero Energy Housing	9
48-xxx	Architectural Technology Elective (pre-approval required)	

Minimum Units: 54

Minor in Building Science

Available to architecture majors only (minimum 54 units total)

The Minor in Building Science is intended for those students that want to deepen their knowledge in the building sciences and for those who are interested in gaining advanced placement (AMP) in the M.S. programs offered by the School in the areas of Building Performance & Diagnostics (MSBPD) and Sustainable Design (MSSD). It is earned by completing the two required building technology and three environmental science courses and then an additional three elective courses in the building sciences.

Required Course 12 units

48-722	Building Performance Modeling	12

Selective Courses 45 units

48-795	LEED	6
48-721	Building Controls and Diagnostics	12
48-723	Performance of Advanced Building Systems	Var.
48-729	Sustainability, Health and Productivity to Accelerate a Quality Built Environmen	9-12
48-749	Special Topics in Computational Design	6
48-752	Zero Energy Housing	9

Minimum Units: 54.

Minor in Architectural Design Fabrication

Available to architecture majors only (minimum 63 units total)

The Minor in Architectural Design Fabrication is intended for those who wish to develop focused, disciplinary expertise in both analog and digital material methods for shaping the built environment and become involved in a community of practice dedicated to a rigorous pursuit of *making* as a mode of architectural research and cultural expression. It is also for students interested in gaining advanced placement in the SoA's Master of Advanced Architectural Design (MAAD) program.

Required Courses 30 units

48-531	Fabricating Customization: Prototype	9
48-545	Design Fabrication	9
48-555	Introduction to Architectural Robotics	9
48-xxx	ASO Studio with digital fabrication focus	18

Selective Courses 30 units

48-470	The Depth of Surface	9
48-473	Hand and Machine Joinery, New Directions	9
48-xxx	Design Fabrication Independent Study	3-9
xx-xxx	Pre-approved design fabrication course	

Minimum Units: 63.

Minor in Computational Design

Available to both architecture majors and non-architecture majors (minimum 54 units total)

The minor in Computational Design is intended for students who wish to engage with computation as a vehicle of generative, material, and spatial design exploration. It brings together courses from the School of Architecture and the College of Fine Arts to offer students hands-on experience, and a deep understanding, of computation as a resource in creative design practices. Students minoring in computational design will be eligible for advanced standing in the School of Architecture’s Master of Science in Computational Design (MSCD) program. The minor offers students the possibility of exploring three areas of computational design: designing, making, and theory. Please refer to this document (https://static1.squarespace.com/static/54c2a5c7e4b043776a0b0036/t/5f4eb94ce17d4e73ccbbd371/1598994764926/cd_minor_20200829.pdf) for the latest information.

Required Courses 30 units

62-122	Digital Media I	6
62-123	Digital Media II	6
62-225	Generative Modeling	9
62-275	Fundamentals of Computational Design	9

Selective Courses 24 units

Designing		
48-568	Advanced CAD, BIM, and 3D Visualization	9
51-367	Design Center: Computational Design Thinking	9
Making		
48-530	Human-Machine Virtuosity	12
48-545	Design Fabrication	9
48-555	Introduction to Architectural Robotics	9
54-399	Decoding Media	9
54-405	Digital Narratives	5
Theory		

48-727	Inquiry into Computational Design	
48-749	Special Topics in Computational Design	6

Minimum Units: 54.

Art Minor

The Art minor allows undergraduate students outside of the School of Art to pursue a largely studio-based minor in addition to their primary degree. Students can narrowly focus their interest or explore a number of mediums.

To declare an Art minor, students should contact Keni Jefferson (kjefferson@cmu.edu), in the College of Fine Arts, room 300. A portfolio is not required.

Five studio-based courses are required, with a minimum of three studios being Intermediate and/or Advanced. A critical studies course exploring art history and theory is also required.

ART STUDIO COURSES (CHOOSE FIVE) 50 UNITS

		50 units
60-136	Ceramics for Non-Majors	10
60-137	Physical Computing for Non-Majors	10
60-157	Drawing for Non-Majors	10
60-2xx	Intermediate Studio Electives	
60-4xx	Advanced ETB: Electives	
60-4xx	Advanced SIS: Electives	
60-4xx	Advanced DP3: Electives	
60-4xx	Advanced CP: Electives	

Critical Studies (choose one) 9 units

60-105	Cultural History of the Visual Arts	9
60-106	Cultural History of the Visual Arts - the Modern Period	9
60-3xx	Critical Theory Elective	9

Minimum units: 59

Media Design Minor – IDeATe

The minor in *Media Design* is offered by the School of Art as part of the Integrative Design, Arts and Technology (https://ideate.cmu.edu/) (IDeATe) network. IDeATe offers students the opportunity to become immersed in a collaborative community of faculty and peers who share expertise, experience, and passions at the intersection of arts and technology. Students will engage in active "learning by doing" in shared labs and maker spaces. The program addresses current and emerging real-world challenges that require disciplinary expertise coupled with multidisciplinary perspectives and collaborative integrative approaches.

The IDeATe undergraduate curriculum consists of ten areas, all of which can also be taken as minors. The themes of these areas integrate knowledge in technology and arts: Game Design, Animation & Special Effects, Media Design, Design for Learning, Sonic Arts, Innovation and Entrepreneurship, Intelligent Environments, Physical Computing, Soft Technologies, and Immersive Technologies in Arts & Culture. For more information about the IDeATe network, please see Undergraduate Options (p.).

The IDeATe *Media Design* minor invites students on a wide-ranging exploration of the digital media landscape. This multifaceted program encourages a holistic engagement with media technologies and practices, offering an opportunity to embrace the full breadth of media arts disciplines within the IDeATe network. Students gain the skills to design experiences across various platforms, from mobile devices to performances and large-scale installations, while gaining an understanding of how technology and content relate in new media systems, and how meanings are made in these evolving forms.

The flexibility inherent in the *Media Design* minor allows students to create a learning pathway that mirrors their unique interests, integrating elements from the other IDeATe minors. This approach makes it an ideal option for students who wish to experience the broad tapestry of digital media arts or those yet to pinpoint their exact focus within this dynamic field. The *Media Design* minor therefore cultivates versatile media practitioners, ready to innovate within the diverse and rapidly evolving digital media arena.

Curriculum

One Computing Course - Minimum of 9 Units

		Units
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
60-212	Intermediate Studio: Creative Coding	12

One IDeATe Portal Course - Minimum of 9 Units

		Units
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis Recommended Portal Course for this area	10
16-223	IDeATe Portal: Creative Kinetic Systems	10
18-090	Twisted Signals: Multimedia Processing for the Arts	10
53-322	IDeATe: Little Games/Big Stories: Indie Roleplaying Game Studio	9
60-125	IDeATe: Introduction to 3D Animation Pipeline	12
60-223	IDeATe Portal: Introduction to Physical Computing	10
82-250	Digital Realities: Introducing Immersive Technologies for Arts and Culture	9
99-361	IDeATe Portal Sec A: Learning about Learning; Sec B: Intelligent Environments	9

IDeATe Media Design Courses - Minimum of 27 Units

		Units
05/18-540	Rapid Prototyping of Computer Systems	12
15-294	Special Topic: Rapid Prototyping Technologies	5
15-394	Intermediate Rapid Prototyping	5
16/54-375	IDeATe: Robotics for Creative Practice	10
24-672	Special Topics in DIY Design and Fabrication	12
51-236	Information Design	9
51-400	Transition Design	9
53-250	Immersive Experience Pre-production Process	9
53-312	Guest Experience in Theme Park Design	9
53-376	360 Story and Sound	12
53-558	Reality Computing Studio	12
54-399	Decoding Media	9
60-110	Foundations: Time-Based Media	10
60-428	Advanced ETB: Drawing with Machines	12
60-461	Advanced ETB: Experimental Capture	12
62-362	IDeATe: Electronic Logics && Creative Practice	12
62-478	IDeATe: digiTOOL	9
67-240	Mobile Web Design & Development	9
67-265	Design Fundamentals: Shaping Interactions and Experiences	9
67-338	Information & Grid Design	9
76-374	Mediated Narrative	9
82-285	Podcasting: Language and Culture Through Storytelling	9

Additional course options as available. Please refer to the IDeATe website for courses for the current and upcoming semester.

Double-Counting

Students may double-count up to two of their *Media Design* minor courses toward requirements for other majors or minors.

Design Minor

Minoring in Design is a great way for students to diversify their studies and incorporate design skills and thinking into their overall academic experiences. Students who are already School of Design majors are not eligible to earn a Design minor. The 54 required units must be unique to the Design minor. No courses may be double counted.

Requirements and Electives

For a design minor, students must complete 54 units: 27 units of required courses, plus 27 units of design electives.

Required Design Courses

Three required courses:

51-262	Design Center: Communication and Digital Design Fundamentals (formerly CDF)	9
or 51-261	Communication & Digital Design Fundamentals	
51-264	Product Design Fundamentals: Design for Interactions for Products (formerly IDF)	9
51-173	Human Experience in Design	9

Three Design Electives:

51-xxx	Design Elective	9
51-xxx	Design Elective	9
51-xxx	Design Elective	9

Applications

Students must submit transcripts, personal statements, and completed applications by the beginning of February, and submit portfolios or design projects by the beginning of March. They must also obtain permission to complete minors from their major advisors. The minor application form includes detailed requirements.

Admission depends mainly on a student's demonstration of design skills and aptitude. Students are notified of acceptance by the end of March.

If you are interested in applying for the Minor in Design, please contact Design Advisor, Melissa Cicozi (cicozi@cmu.edu). You can download the Design Project and Application at www.design.cmu.edu (http://www.design.cmu.edu), or paper applications are available at the School of Design office, MMCH 110.

Drama Minor

The Drama minor provides students with a well-rounded opportunity to obtain preliminary professional exposure to the theatre arts. Courses may involve acting, directing, playwriting, design, production technology and management, and dramatic literature courses. Students also become involved with Drama productions by signing up for Production for Non-Majors, which involves evening crew work on various Drama productions.

Admission Requirements

1. Students must apply to enter the program in the office of the Drama Academic Advisor.
2. The student must successfully pass one Drama course prior to being considered for minor status.

Required Courses 25 units

54-163	Production for Non Majors (needs to be taken twice for a total of 12 units)	6
54-175	Conservatory Hour	1
54-177	Foundations of Drama I	6
54-281	Foundations of Drama II	6

Students must meet with the School of Drama Production Manager (PCA 224) for assignments related to Production for Non-Majors.

Elective Courses 30 units

The remainder of the minor is fulfilled with Drama courses of the student's choosing, with approval from the Drama Academic Advisor. For certain courses, students may need instructor permission to register.

SAMPLE: Selected Elective Courses not requiring instructor permission:

54-187	Writing for an Inspired Life	9
54-190	Intro to Writing the Television Pilot	9
54-191	Acting for Non-Majors	9
54-193	Acting for Non-Majors: Improv	9
54-196	Introduction to 10-Minute Plays	9

SAMPLE: Selected Elective Courses requiring instructor permission:

54-109	Dramaturgy 1: Approaches to Text	9
54-121	Directing I: A Director's Mindset	9
54-157	Production Science	6
54-169	Studiocraft 1	13
54-171	Basic Design 1	6

Additional Drama Courses are available by instructor agreement and may require an audition, interview, or portfolio review. Students should contact the Drama Academic Advisor, to inquire about permission for specific courses in which they are interested.

Minimum units required: 55

Music Minors

Minor in Music

This sequence is for candidates who are majors from any discipline in the university other than music who have some background in music and would like to know more about music.

Admission Requirements:

1. The student must apply online to enter the program by submitting the minor application that is available here (https://www.cmu.edu/cfa/music/current-students/guidelines-forms/music-minor.html) on the Current Students website.

Prerequisite Course 0–3 units

Beginning Piano for Minors is required of students who do not pass a beginning piano proficiency test.

57-329	Beginning Piano for Minors	3

Required Music Courses 25 units

Basic Harmony I and/or Basic Solfege I are required of students who do not qualify for entrance into Harmony I and/or Solfege I, based on their scores on the theory and solfege placement tests. These classes fulfill the harmony and solfege requirements.

57-152	Harmony I	9
57-161	Eurhythmics I	3
57-181	Solfege I	3
57-173	Survey of Western Music History	9
57-188	Repertoire and Listening for Musicians	1

Required Studio Courses (studio fee is charged) 24 units

57-1xx	Elective Studio	6
57-1xx	Elective Studio	6
57-1xx	Elective Studio	6
57-1xx	Elective Studio	6

Elective Courses 18 units

Elective courses are to be chosen from those courses listed for the School of Music in the current course catalog. Performance electives are encouraged. (An audition is required for all School of Music performance ensembles.)

Minimum units required: 67

Minor in Music Technology

This sequence is for candidates who are majors from any discipline in the university who have some background in music and would like to know more about music technology.

Note: Students in the School of Music have slightly different requirements for the Minor in Music Technology. See School of Music (p.).

Admission Requirements

1. The student must apply online to enter the program by submitting the minor application that is available here (https://www.cmu.edu/cfa/music/current-students/guidelines-forms/music-minor.html) on the Current Students website.

Prerequisite Course 0–3 units

Beginning Piano for Minors is required of students who do not pass a beginning piano proficiency test.

57-329	Beginning Piano for Minors	3

Required Music Courses 25 units

Basic Harmony I and/or Basic Solfege I are required of students who do not qualify for entrance into Harmony I and/or Solfege I, based on their scores on the theory and solfege placement tests. These classes fulfill the harmony and solfege requirements.

57-152	Harmony I	9
57-161	Eurhythmics I	3
57-173	Survey of Western Music History	9
57-181	Solfege I	3
57-188	Repertoire and Listening for Musicians	1

Sound Recording Courses 21 units

57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-438	Multitrack Recording	9

Music Technology/Sound Courses (choose at least three) 21 units

Choose at least three courses. One of the three courses must be either Introduction to Computer Music or Electronic and Computer Music. (Note that 15-112 is a prerequisite for 15-322; 57-101 or 57-171 is a prerequisite for 57-347.) Other courses may be taken with the permission of the music technology minor advisor.

15-104	Introduction to Computing for Creative Practice	10
15-322	Introduction to Computer Music	9
18-090	Twisted Signals: Multimedia Processing for the Arts	10
33-114	Physics of Musical Sound	9
54-166	Introduction to Sound Design for Theatre	6
57-344	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music	6
57-478	Survey of Historical Recording	6
57-421	Exploded Ensemble	6

Minimum units required: 67

Minor in Music Theory

This sequence is for candidates who are majors from any discipline in the university who have some background in music and would like to know more about music theory.

Note: Students in the School of Music have slightly different requirements for the Minor in Music Theory. See School of Music (p.).

Admission Requirements

1. The student must apply online to enter the program by submitting the minor application that is available here (https://www.cmu.edu/cfa/music/current-students/guidelines-forms/music-minor.html) on the Current Students website.

Prerequisite Course 0–3 units

Beginning Piano for Minors is required of students who do not pass a beginning piano proficiency test.

57-329	Beginning Piano for Minors	3

Required Music Courses 25 units

Basic Harmony I and/or Basic Solfege I are required of students who do not qualify for entrance into Harmony I and/or Solfege I, based on their scores on the theory and solfege placement tests. These classes fulfill the harmony and solfege requirements.

57-152	Harmony I	9
57-161	Eurhythmics I	3
57-173	Survey of Western Music History	9
57-181	Solfege I	3
57-188	Repertoire and Listening for Musicians	1

Required Theory Courses 21 units

57-151	Counterpoint in Theory and Application	6
57-153	Harmony II	9
57-408	Form and Analysis	6

Upper Level Theory Course (choose one) 6 units

See theory courses on the Music Support Courses Two-Year Rotation list. It is available here (https://www.cmu.edu/cfa/music/current-students/music-support-courses-f231.pdf) on the Current Student website. A graduate course may be taken with the permission of the instructor.

Elective Courses 18 units

Elective courses are to be chosen from those courses listed for the School of Music in the current course catalog.

Minimum units required: 70

Sonic Arts Minor – IDeATe

Sonic Art is a creative expression that uses sound as its primary medium. Just as visual artists create landscapes, portraits, and narratives through light, color, and form, sonic artists craft transformative experiences through sound, noise, and music.

Students in the *Sonic Arts* minor explore the processes and products of digital sound design and music production. They receive basic training in key component areas: principles of computer music, sound synthesis, spatialization, and core practices in sound design. Combining this training with courses that bring together experts from many disciplines, they create experimental music and explore emerging applications and markets for sound design, music creation, and performance.

Curriculum

One Computing Course - Minimum of 9 Units

		Units
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
60-212	Intermediate Studio: Creative Coding	12

One IDeATe Portal Course - Minimum of 9 Units

		Units
18-090	Twisted Signals: Multimedia Processing for the Arts Other IDeATe Portal Course by permission only. Consult the IDeATe advisor.	10

IDeATe Sonic Arts Courses - Minimum of 27 Units

		Units
15-322	Introduction to Computer Music	9
33-114	Physics of Musical Sound	9
54-166	Introduction to Sound Design for Theatre	6
54-267	Conceptual Sound Design	9
54-509	Theatrical Sound System Design 2	9
57-337	Sound Recording	6
57-344/60-407	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music	6
57-358	Introduction to Electronic Music portfolio required for registration	9
57-359	Audiovisual Composition	9
57-421	Exploded Ensemble	6
57-458	Business of Music	6
Additional course options as available. Please refer to the IDeATe website for courses for the current and upcoming semester.		

Double-Counting

Students may double-count up to two of their *Sonic Arts* minor courses for other requirements.

CFA Dean's Office Minors

Minor in the History of Arts

This minor of six or more courses as designated below, offers students flexibility to engage in a broad survey in the arts or can be tailored to reflect a more specific area of interest. For College of Fine Arts students, all courses meeting the requirements of the Minor in the History of the Arts must be taken outside of their major School, with the exception of the School of Architecture. Interested students should contact Stefanie McGowan (stefanim@andrew.cmu.edu) in the College of Fine Arts, Room 100.

Introductory Level Courses 27 units

(choose at least three, CFA students pick 3 outside of major)

48-240	History of World Architecture, I	9
48-241	History of Modern Architecture	9
54-239	History of Architecture and Decor 1: Ancients to Gothic	Var.
54-240	History of Architecture and Decor 2: Renaissance to the 21st Century	Var.
54-245	Who Wore What: When, Where, and Why (instructor permission only)	Var.
54-246	Who Wore What: When, Where, Why II (instructor permission only)	Var.
57-173	Survey of Western Music History (coreq: 57-188)	9
57-188	Repertoire and Listening for Musicians (coreq of 57-173)	1
60-105	Cultural History of the Visual Arts (instructor permission only)	9
60-106	Critical Theory in Art II	9

Intermediate/Advanced Level Courses 27 units

(choose at least three, CFA students pick 3 outside of major)*

48-348	Architectural History of Mexico & Guatemala	9
48-374	History of Architecture in the Islamic World- A Primer (prereq: 48-240)	9
51-376	Semantics & Aesthetics	4.5
57-209	The Beatles	9
57-476	How Music Works: An Affective History	6
57-477	Music of the Spirit	6
57-478	Survey of Historical Recording	6
57-480	History of Black American Music	6
57-485	History of the Symphony	9
Art Critical Studies Electives: 60-352 to 60-398 (instructor permission only)		9
62-360/79-328	Photographers and Photography Since World War II	9
62-371/79-316	Photography, The First 100 Years, 1839-1939	9
79-395	The Arts in Pittsburgh	9

Minimum units required for minor: 54

*Other courses not on this list may qualify as approved by CFA Dean's Office (College of Fine Arts, Room 100).

Minor in Photography

The Photography Minor exposes students to the breadth of offerings from traditional photography (i.e. film exposure and silver printing) to digital shooting and output. The student will become familiar with photography's craft, its history and significant practitioners, and develop their own distinct engagement with the medium.

Students may apply for the Photography Minor after they have taken a beginning photography course. Students will be admitted to the minor based on their aptitude, appropriate level of photography skills, and space availability within the program. Once admitted, students will be assigned a faculty advisor who will help them determine a sequence of courses that best fits their needs and interests.

Application Requirements

The application process for the Photography Minor requires submission of: a completed application form signed by the home department advisor, a personal statement, and a portfolio of photographs. Contact the CFA Photography Administrator, Jamie Gruzska (gruzska@andrew.cmu.edu), MM B18, for further information. Applications are processed every semester.

Photography Required Courses (3) minimum 30 units

62/60-141	Black and White Photography I *	10
62/60-142	Digital Photography I	10
62/60-241	Black and White Photography II	10

Photography Elective (1) minimum 10 units

Choose one (1) or more additional photography course. Recent offerings are listed below, some are offered intermittently; consult Jamie Gruzska for current offerings.

62-245	Portrait Photography	10
62-375	Large Format Photography: The Antiquarian Avant-Garde	10
62-343	Professional Practices in Photography	10
62-279	Photography and the Ineffable	10

Photo History Required Course (1) minimum 9 units

62-371	Photography, The First 100 Years, 1839-1939 *	9
or 62-360	Photographers and Photography Since World War II	

History, Theory, or Criticism of the Visual Arts Elective (1) minimum 9 units

Choose one (1) additional History, Theory or Criticism of the Arts course in consultation with the photo advisor. A second Photo History course (62-360 or 62-371) can be used for this requirement.

*or course approved by the photography advisor

Minimum units required for minor: 58

School of Architecture

Omar Khan
Location: CFA 201
www.soa.cmu.edu (http://www.soa.cmu.edu)

The SoA educates students in the discipline of architecture emphasizing the role of creativity in architectural design; understanding its historical, social and environmental context; critically engaging technology in its innovation; and ethically working for social progress and justice in the built environment. Our undergraduate and graduate degree programs prepare students for the challenges facing architecture and urbanism in the twenty-first century, namely global warming, artificial intelligence and social justice. We aim to produce discipline-defining designers and thinkers in diverse global contexts.

This world-class architecture education is enhanced by our position within one of the world's leading research and entrepreneurship institutions, and by the fundamental premise that architectural excellence demands both rigorous training in fundamentals and the development of unique specializations. Students may extend their core knowledge either through concentration in architecture subdisciplines like urban design, sustainable design or computational design, or through interdisciplinary interaction with CMU's other renowned programs in the sciences, humanities, business and engineering. Though every SoA student graduates with intensive architecture knowledge, no two graduates leave with the same education.

In the twenty-first century, few architecture problems are straightforward. Graduates of SoA excel in the roles architects have performed for centuries - and in new roles catalyzed by the depth and breadth of their education - to create and execute innovative solutions to a huge range of emerging global challenges.

Undergraduate Degree Programs

The SoA offers two baccalaureate degree programs: the 5-year, professional Bachelor of Architecture (B.Arch), and the 4-year Bachelor of Arts in Architecture (B.A.). Both programs begin with the same studio-based curriculum in the first year, but then begin to diverge in terms of opportunities and outcomes. The B.Arch requires 10 studios and an extensive set of required professional courses, while the B.A. requires a minimum of 4 studios and fewer technical courses, all of which can be spread out over the four years of the program, and thus allow students to explore different opportunities in their studies.

Undergraduate students are admitted to the SoA without a declared degree program. By the end of the second year, students must select either the B.A. or the B.Arch degree program. The student's academic advisors, faculty, and Head provide mentoring and information to guide the student in selecting their degree option.

Bachelor of Architecture Program (B.Arch)

The Bachelor of Architecture (B.Arch) is a 5-year, first professional degree program accredited by the National Architectural Accrediting Board (NAAB, https://www.naab.org/) with a carefully defined set of "Program Criteria" (PC) and "Student Performance Criteria" (SPC). The B.Arch is for students proposing to pursue a career as a licensed architect or related profession, and centers around a carefully structured set of professional and technical courses about building design and construction, alongside the social, cultural and professional contexts in which architects operate. Our students graduate with a professional degree that prepares them to excel in practice—but that also launches them into key specialties within and around the profession.

Due to the technical nature of the B.Arch program at CMU, it is STEM-eligible, meaning that in addition to one year of Optional Practical Training (OPT), an international student on an F-1 visa may apply for a 24-month STEM OPT extension following graduation.

Statement on NAAB-Accredited Degrees

In the United States, most registration boards require a degree from an accredited professional degree program as a prerequisite for licensure. The National Architectural Accrediting Board (NAAB), which is the sole agency authorized to accredit professional degree programs in architecture offered by institutions with U.S. regional accreditation, recognizes three types of degrees: the Bachelor of Architecture, the Master of Architecture, and the Doctor of Architecture. A program may be granted an eight-year term, an eight-year term with conditions, or a two-year term of continuing accreditation, or a three-year term of initial accreditation, depending on the extent of its conformance with established education standards.

Doctor of Architecture and Master of Architecture degree programs may require a non-accredited undergraduate degree in architecture for admission. However, the non-accredited degree is not, by itself, recognized as an accredited degree.

The Carnegie Mellon University School of Architecture offers the following NAAB-accredited programs:
-- Bachelor of Architecture (450 units)
-- Master of Architecture (Pre-professional degree or equivalent + 180 units)

The next NAAB accreditation visit for the Bachelor of Architecture is scheduled for 2026.
The next NAAB accreditation visit for the Master of Architecture is scheduled for 2030.

The full 2020 NAAB Conditions for Accreditation can also be found on NAAB's website at: https://www.naab.org/accreditation/about-accreditation (https://www.naab.org/accreditation/about-accreditation/).

Bachelor of Arts in Architecture Program (B.A.)

The Bachelor of Arts in Architecture (B.A.) is a 4-year liberal studies degree program that allows and encourages interdisciplinary exploration. The program is built around a core foundation of architectural studios and technical coursework, but more than half of the units required for graduation are general studies courses and flexible electives. B.A. students have the opportunity to double major, test the boundaries of the discipline, and explore a variety of interests. If you are a student that embraces creativity, is curious about the world around you, and enjoys engaging both the left and right sides of your brain, the B.A. program could be a perfect fit for you.

As a 4-year, pre-professional architecture program, the B.A. allows those who are interested to continue in architecture with a 2-year professional M.Arch degree program (often called a 4+2 degree), or to go on to specialize in other fields in graduate school, including urban design, landscape architecture or other fields related to design, the built environment, virtual worlds, community engagement, sustainability, and more. The B.A. also makes it possible for students to transfer into architecture from other studies.

In the first year, the B.A. program begins with the same studio-based curriculum as the B.Arch program, but then begins to diverge in terms of opportunities and outcomes. The B.A. requires only the first four studios and the core courses from the first two years of the B.Arch sequence, and these can be spread out over the four years of the program. Students may take more studios, specialize in particular aspects of architecture, or explore broadly.

For students seeking to integrate architecture with another field of study, CMU also offers the BXA Intercollege Degree Programs. BXA students graduate with a Bachelor of Humanities and Arts, a Bachelor of Science and Arts, or a Bachelor of Computer Science and Arts degree.

B.Arch Curriculum

Minimum units required for Bachelor of Architecture 450

First Year: Poeisis

48-100	Architecture Design Studio: POIESIS STUDIO 1	15
48-104	Shop Skills	3
62-122	Digital Media I	6
62-104	Design Ethics & Social Justice in Architecture	3
62-125	Drawing I	6
76-101	Interpretation and Argument	9
99-101	Core@CMU	3

48-105	Architecture Design Studio: Poiesis Studio 2	15
48-112	Digital Fabrication Skills	2
62-123	Digital Media II	6
62-126	Drawing II	6
48-240	History of World Architecture, I	9
xx-xxx	Elective	6

Second Year: Poeisis

48-200	Poiesis Studio 3: Architecture Biome and Climate	18
48-215	Materials & Assembly	9
48-116	Introduction to Building Performance	3
62-225	Generative Modeling	9
48-111	Exploring Pittsburgh	3
xx-xxx	Elective	6

48-205	Architecture Options Studios	18
48-241	History of Modern Architecture	9
48-234	Introduction to Structures	6
62-275	Fundamentals of Computational Design	9
48-xxx	Seminar II	3
xx-xxx	Elective	3

Third Year: Praxis

48-300	Architecture Design Studio: Praxis Studio 1	18
48-315	Environmental Systems: Climate & Energy in Buildings	9
48-250	Urbanism and the Social Production of Space	6
48-xxx	Structures 2	9
xx-xxx	Elective	6

48-305	Architecture Design Studio: Praxis Studio 2	18
48-380	Constructing Value(s): Economies of Design	6
48-xxx	Architectural History3 (Selective)	9
xx-xxx	Elective	3

Fourth Year

48-400	Architecture Design Studio: Praxis Studio 3	18
48-432	Environment II: Design Integration of Active Building Systems	9
48-xxx	Professional Development	3
xx-xxx	Elective	9
xx-xxx	Elective	4

48-405	Advanced Synthesis Options Studio II	18
48-381	Issues of Practice	6
48-383	Ethics and Decision Making in Architecture	6
xx-xxx	Elective	9
xx-xxx	Elective	4

Fifth Year

48-500	Advanced Synthesis Options Studio	18
xx-xxx	Elective	9
xx-xxx	Elective	9
xx-xxx	Elective	6

48-510	Advanced Synthesis Options Studio IV	18
or 48-519	Architecture Design Studio: Thesis II/ Independent Project	
xx-xxx	Elective	9
xx-xxx	Elective	9
xx-xxx	Elective	6

B.A. Curriculum

Minimum units required for Bachelor of Arts in Architecture	360

Design Studios

48-100	Architecture Design Studio: POIESIS STUDIO 1	15
48-105	Architecture Design Studio: Poiesis Studio 2	15
48-200	Poiesis Studio 3: Architecture Biome and Climate	18
48-205	Architecture Options Studios	18

Architecture Coursework

48-104	Shop Skills	3
48-116	Introduction to Building Performance	3
48-112	Digital Fabrication Skills	2
48-111	Exploring Pittsburgh	3
48-240	History of World Architecture, I	9
48-241	History of Modern Architecture	9
48-250	Urbanism and the Social Production of Space	6
48-215	Materials & Assembly	9

General Studies

99-101	Core@CMU	3
48-025	First Year Seminar: Architecture Edition I	3
76-101	Interpretation and Argument	9
62-104	Design Ethics & Social Justice in Architecture	3
62-122	Digital Media I	6
62-123	Digital Media II	6
62-125	Drawing I	6
62-126	Drawing II	6
62-225	Generative Modeling	9
48-234	Introduction to Structures	6
62-275	Fundamentals of Computational Design	9
48-xxx	Seminar II	3

Electives

48-xxx	Architecture Electives	45
xx-xxx	University Electives (Outside SoA)	45
xx-xxx	Flex Electives (In or out of SoA)	92

Minors in Architecture

The SoA offers several minors in various specialty subjects related to architecture, some are only available to non-architecture students, others are only available to architecture majors, and still others can be taken by all CMU students. For the most up-to-date list of minors, see: https://www.architecture.cmu.edu/minors (https://www.architecture.cmu.edu/minors/).

Non-architecture students may minor in: Architecture, Architectural History, Architectural Representation & Visualization, Architectural Technology, and Computational Design.

Architecture majors may minor in: Architectural Design Fabrication, Architectural History, Architectural Representation & Visualization, Building Science, and Computational Design.

The **Minor in Architecture** sequence is for students who intend to develop intellectual links to the architectural profession. The scope of courses offered includes a full spectrum of professional issues in architecture. (*Available to non-architecture majors only.)*

The **Minor in Architectural Design Fabrication** is intended for students who wish to develop focused, disciplinary expertise in both analog and digital material methods for shaping the built environment and become involved in a community of practice dedicated to a rigorous pursuit of *making* as a mode of architectural research and cultural expression. It is also for students interested in gaining advanced placement in the SoA's Master of Advanced Architectural Design (MAAD) (https://soa.cmu.edu/maad/) program. *(Available to architecture majors only.)*

The **Minor in Architectural History** is intended for candidates interested in the history of architecture in its many manifestations, including high style and vernacular buildings, western and non-western traditions, built and theoretical works, and rural to urban contexts. Students wishing to pursue the minor should meet with the Architecture advisor to determine if a course is eligible. *(Available to both architecture majors and non-architecture majors.)*

The **Minor in Architectural Representation and Visualization** is intended for students who wish to develop particular skills in architectural representation, and for those who are interested in gaining advanced placement in the SoA's Master degree program in Computational Design (MSCD) (https://www.architecture.cmu.edu/computational-design/). *(Available to both architecture majors and non-architecture majors.)*

The **Minor in Architectural Technology** is intended for students who seek to develop intellectual links to the technical aspects of the profession. (*Available to non-architecture majors only.)*

The **Minor in Building Science** is intended for students that want to deepen their knowledge in the building sciences, and for those who are interested in gaining advanced placement in the SoA's Master degree programs in Building Performance & Diagnostics (MSBPD) (https://soa.cmu.edu/bpd/) or Sustainable Design (MSSD) (https://soa.cmu.edu/mssd/). *(Available to architecture majors only.)*

The **Minor in Computational Design** is intended for students who wish to engage with computation as a vehicle of generative, material, and spatial design exploration, and for those who are interested in gaining advanced placement in the SoA's Master of Science in Computational Design (MSCD) (https://soa.cmu.edu/mscd/). *(Available to both architecture majors and non-architecture majors.)*

Advanced Standing in Master Degree Programs

The SoA offers a unique opportunity to undergraduate students who wish to pursue a post-professional Master's degree in an architecture-related field. The Accelerated Master's Program (AMP) (https://soa.cmu.edu/accelerated/) offers baccalaureate students the opportunity to expedite their completion of a Master's degree, saving both time and money—and allowing them to hit the job market with specialized knowledge and two CMU degrees. Baccalaureate students can pursue a graduate degree in the following subjects: Master of Architecture (M.Arch) (B.A. students only), Advanced Architectural Design, Architecture–Engineering–Construction Management, Building Performance and Diagnostics, Computational Design, Sustainable Design, and Urban Design. An AMP student must complete all of the units required by BOTH programs, less a maximum of 48 units that can be double-counted. For instance, B.Arch + MSSD-Applied would be 450 units + 135 units less 48 double-counted units, or 537 total units total for two degrees. B.Arch students may begin pursuit of a post-professional Master's degree through AMP as early as their third year.

Graduate Degree Programs

Carnegie Mellon University is recognized for outstanding contributions to science, technology, management, policy, and the fine arts. The School of Architecture builds on a tradition of interdisciplinary study. **The School of Architecture offers seven (7) Master's degrees, and three (3) Doctoral degrees in the following areas of study:**

Master of Advanced Architectural Design

The Master of Advanced Architectural Design (MAAD) (https://www.architecture.cmu.edu/maad/) is a post-graduate, studio-based program that engages emerging methods of design and fabrication through architectural design to speculate upon future modes of architectural practice, enhanced construction methods, and material culture within the built environment.

Master of Architecture

The Master of Architecture (M. Arch) (https://www.architecture.cmu.edu/march/) is two-year, studio-based, NAAB-accredited (https://www.architecture.cmu.edu/accreditation/), first professional degree program to educate tomorrow's leaders in architecture-related careers. It requires a 4-year, pre-professional architecture program such as the B.A. or its equivalent to enroll, and is thus often called a 4+2 degree. The M.Arch program provides both the broad, comprehensive training in fundamentals required for U.S. professional registration and licensure, and the opportunity to focus on, speculate in, and obtain dual degrees with other research-based master's programs in the SoA. Our M.Arch program's strategically small size allows our self-motivated students to shape their individual educational agendas and career paths as they interact directly with a broad array of vertically integrated studios and advanced research projects in the school, the university, the local community, and around the world.

Master of Science/Doctor of Philosophy in Architecture–Engineering–Construction Management

A joint effort between the School of Architecture and the Department of Civil & Environmental Engineering, the Architecture–Engineering–Construction Management (AECM) (https://www.architecture.cmu.edu/aecm/) programs prepare building delivery professionals for careers in capital project delivery dealing with the entire life-cycle of capital projects, from pre-design to design, construction, commissioning, operation, and maintenance stages. Graduates are educated to become effective decision makers who can positively impact economic, environmental, and ethical aspects of the built environment through professional management strategies. Our graduates have successful careers in government, industry, business, and NGO (non-governmental organization) sectors, prospering in positions where design professionals continuously make large-scale capital project design, construction, and maintenance decisions.

Master of Science/Doctor of Philosophy in Building Performance and Diagnostics

Our graduate programs in Building Performance & Diagnostics (BPD) (https://www.architecture.cmu.edu/bpd/) have long led the world in advanced building technologies that sustainably reshape the built environment. BPD deals with the comprehensive integration of *building design* and *advanced technology*, as a means of producing high performance architecture. Led by the Center for Building Performance & Diagnostics (CBPD) (https://soa.cmu.edu/cbpd/) and housed within the Robert L. Preger Intelligent Workplace, students have the opportunity to gain both diversity and depth of knowledge from world-renowned and experienced faculty.

Master of Science/Doctor of Philosophy in Computational Design

Our graduate programs in Computational Design (https://www.architecture.cmu.edu/computational-design/) (CD) are among the first and best known in the country, and our legacy continues today. The Computational Design program takes a computer science view of design, applying both the science and art of computing to design problems, in relation to creation, presentation, analysis, evaluation, interaction or aesthetic expression; in real and imagined applications, both perceived and conceived. From the beginning, the program has benefitted from close cooperation with other units of the university, particularly the School of Computer Science and the Department of Civil & Environmental Engineering. Our research-based degree programs are intended for practitioners, educators and researchers in architecture, computer science, engineering and those interested in design. Our graduates go on to successful careers in government, industry, academia, and software development.

Master of Urban Design

The Master of Urban Design (MUD) (https://www.architecture.cmu.edu/mud/) is a studio-based program distinguished by its emphasis on integrating socially engaged practice with new tools and techniques for representing, understanding, and designing cities; by the opportunity to work in trans-disciplinary teams at the intersection of the arts, humanities and technology across Carnegie Mellon's departments and colleges; and by its location in Pittsburgh—a thriving post-industrial laboratory.

MASTER OF SCIENCE IN SUSTAINABLE DESIGN

The Master of Science in Sustainable Design (MSSD) (https://www.architecture.cmu.edu/mssd/) is a post-professional research-based graduate program focused on enabling deep expertise, critical thinking, and investigation of innovative sustainable strategies for the design of the built environment. The MSSD program explores technical and multicultural aspects of ecological thinking, while enabling actionable expertise in sustainable design methodologies. Based in the legacy of sustainability teaching at Carnegie Mellon University, the MSSD program prepares students to excel in research methods, and to become experts in integrative design thinking for the future of the built environment.

Student Advising

Architecture students can receive advice from many sources, including the faculty, staff, and administration of the School. All SoA undergraduates are urged to meet with the Senior Academic Advisor to review their academic progress and plans before each semester. Such meetings are important to take full advantage of elective possibilities within the curriculum, general progress toward graduation, and professional goal-setting. Students may also check their progress using the online academic audit in the Student Information Online (SIO) and should review the audit results with the senior academic advisor. The Academic Advisor will assist students with registration, academic audits, transfer credits, study abroad, SoA minors, finals grades and academic actions, as well as SoA and university policies and resources.

In addition, we encourage all of our students to become involved with student organizations such as AIAS or NOMAS, as well as committees such as the Student Advisory Council (SAC) in order to learn from peers. Students should seek advice about the Architectural Experience Program (AXP) and architectural licensing through the Architect Licensing Advisor

Study Abroad

The SoA strongly encourages students to study abroad. The perspective gained through immersion in another culture and language is invaluable. A student is exposed to architectural subjects not readily available at CMU and will study architecture directly in a foreign context. The Office of International Education (OIE) is an excellent resource for getting started for study abroad planning.

Study abroad can fall into four categories: University Direct Exchanges, University Sponsored Programs, External Programs, and Departmental Summer Programs.

Students are allowed one semester abroad for which they receive studio credit except for those students at approved direct, year-long exchange programs. Students may study abroad in the Fall, Spring, or Summer semesters. Careful planning and scheduling of your courses are necessary when incorporating a study away experience into your curriculum. Students should investigate and start making decisions to study abroad by the fall of their second year, so they can plan their courses accordingly. Please see the academic advisor prior to making any decisions on what term to schedule your study away experience.

To qualify for a study abroad program other than the departmental summer programs, a student must have completed their third year of the program, have a minimum overall QPA of 3.00, and be in good academic standing (no current academic actions).

Students in SoA departmental summer programs must have completed their first year, and must be free of any academic actions for the semester prior to studying away, or permission may be denied. Students can petition the UPEC for exceptions.

Students who participate in a study abroad program for one semester will transfer non-studio course credit by submitting course descriptions of each course taken as well as an official transcript from the host Institution. Official translated transcripts must be submitted to the academic advisor before the beginning of the academic year to receive transfer credit. Grades are not transferred, only credits. Transfer credit is awarded upon receipt of an official translated transcript and only for courses with the grade of a C or better (not C-). When students return from study abroad, they must pin up original work during the study away exhibit, which will be subject to review by the UPEC or designated faculty.

Faculty

JARED ABRAHAM, Associate Studio Professor

VICKY ACHNANI, Associate Studio Professor

NILOUFAR ALENJERY, Special Faculty

SAROSH ANKLESARIA, Assistant Teaching Professor

MARY-LOU ARSCOTT, Studio Professor & Associate Head

NINA BARBUTO, Adjunct Faculty

JOSHUA BARD, Associate Professor & Associate Head

WILLIAM BATES, Adjunct Faculty

HEATHER BIZON, Special Faculty

DARAGH BYRNE, Associate Teaching Track

DANIEL CARDOSO LLACH, Associate Professor

GLORIA CHANG, Special Faculty

XIN CHEN, Adjunct Instructor

JIMMI WEI-CHUN CHENG, Special Faculty

LORI CLAUS, Special Faculty

ERICA COCHRAN HAMEEN, Associate Professor & Director of DEI

DOUG COOPER, Andrew Mellon Professor

DANA CUPKOVA, Professor

GERARD DAMIANI, Associate Professor

STEFANI DANES, Adjunct Faculty

ASLI DARGA,, Adjunct Faculty

JEFFREY DAVIS, Adjunct Faculty

JEREMY FICCA, Associate Professor, Director dFAB

KRISTINA FISHER, Adjunct Faculty

LAURA GARAFALO, Associate Professor

SINAN GORAL, Adjunct Faculty

BRAD GROFF, Adjunct Faculty

STEFAN GRUBER, Associate Professor

KAI GUTSCHOW, Associate Professor & Associate Head

NAJEEB HAMEEN, Adjunct Faculty

TOM HARDY, Adjunct Faculty

VOLKER HARTKOPF, Professor Emeritus

HAL HAYES, Studio Professor

NEAL HITCH, Special Faculty

JOHN HOLMES, Shop Director

MATTHEW HUBER, Adjunct Faculty

THEODOSSIS ISSAIAS, Special Faculty

MARYAM KARIMI, Special Faculty

LYNN KAWARATANI, Liason Librarian to SoA

OMAR KHAN, Professor & Head

JEFF KING, Adjunct Faculty

JONATHAN KLINE, Studio Professor

RAMESH KRISHNAMURTI, Professor Emeritus

MATTHEW KRISSEL, Adjunct Faculty

KRISTEN KURLAND, Teaching Professor

JONGWAN KWON, Assistant Teaching Professor

KHEE POH LAM, Professor Emeritus

JOSHUA D. LEE, Assistant Professor

JUNEY LEE, Assistant Professor

STEPHEN R. LEE, Professor Emeritus

SUZI ZEKUN LI, Graduate Instructor

NICK LIADIS, Adjunct Faculty

VIVIAN LOFTNESS, University Professor, Paul Mellon Professor

JACKIE JOSEPH PAUL MCFARLAND, Special Faculty

CHRISTINE MONDOR, Special Faculty

YAEL NETSER, Graduate Instructor

MELANIE NGAMI, Adjunct Instructor

RICHARD NISA, Adjunct Faculty

VERNELLE NOEL, Assistant Professor

PAUL OSTERGAARD, Adjunct Faculty

YIQUN PAN, Special Faculty

PAUL PANGARO, Visiting Scholar in Computational Design

MISRI PATEL, Anne Kalla Visiting Professor

STEPHEN QUICK, Adjunct Faculty

NIDA REHMAN, Assistant Professor

AZADEH OMIDFAR SAWYER, Assistant Professor

NATHAN SAWYER, Special Faculty

CHARLIE SCHMIDT, Adjunct Instructor

DIANE SHAW, Associate Professor

TULIZA SINDI, Anne Kalla Visiting Professor

STEVEN SONTAG, Assistant Shop Director

BEA SPOLIDORO, Adjunct Faculty

ANDREW STONE, Thomas Visiting Professor

LOUIS SUAREZ, Adjunct Faculty

NAZIA TARRANUM, Adjunct Faculty

FRANCESCA TORELLO, Special Faculty

ALICIA VOLCY, Adjunct Faculty

GARRET WOOD-STERNBURGH, Adjunct Instructor

HEATHER WORKINGER MIDGLEY, Adjunct Faculty

TOMMY CHEEMOU YANG, Associate Studio Professor

School of Architecture Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

48-025 First Year Seminar: Architecture Edition I

Fall: 3 units
The main objective of this first-year seminar course is on how students learn, develop, and make decisions as they transition into architecture education. The goal of this course is to promote academic success and encourage connections within the SoA and the University at large. Teaching and learning strategies will be introduced to help support the transition into architecture and the development of independent critical thinkers. Students will be introduced to campus resources that support their academic/social/personal integration into the campus community. Topical areas to be covered in the seminar will include academic success strategies in architecture education, academic development, career planning, mentorship, academic and personal support services, and the aspects of professional practice in architecture.

Course Website: https://soa.cmu.edu/courses (https://soa.cmu.edu/courses/)

48-095 Spatial Concepts for Non-Architecture Majors

Fall and Spring: 10 units
This course serves as an introduction to the spatial concepts of architecture for students from other disciplines. The course is focused entirely on project design work (this is not an historical survey, technical or lecture course). This course is very hands-on Projects will explore the design and experience of spatial environments through a series of creative investigations. The semester will be broken in to 3 parts:Intro/Exploration and a long term project. In Intro/Exploration, students will have many hands on opportunities to start to build a common language to describe spacial investigations as well as creating them. This will consist of short projects, with each design investigation progressively building upon the previous exploration; these early projects will consist of both individual and group work. They will focus on Making. The second half of the semester will consist of one long term project to be created individually, incorporating students? personal theories of architecture based on an overarching question. Studio work will be supported by group discussion based upon critical review of student work, readings, slide presentations, videos and films. There will also be a few field trips. Students are encouraged to explore their own areas of interest with respect to their work in class. Self-motivation, class attendance and an open mind is mandatory, however, no prior architectural, engineering or artistic experience is required. Students are expected to perform work both inside and outside of class. Students should be prepared to purchase various supplies throughout the course. This course is in partial fulfillment of requirements for an Architecture Minor.

48-100 Architecture Design Studio: POIESIS STUDIO 1

Fall: 15 units
This studio will investigate the role and process of architectural design as different forms of practice. The studio will practice drawing, making, and building architectural narratives in iterations at various scales of time and space, to establish productive habits and develop essential techniques and skills in architectural design. In learning how architects see in both visible and invisible terms, the studio will analyze design precedents and problems that generate ideas about architectural material, form, and systems. In understanding how architects empathize with whom or what they serve, the studio will rigorously investigate methods of abstraction and critical dimensions relative to human form and experience. In practicing how architects deliver in the professional context, the studio will develop mastery of spatial composition, representation, and narrative as means for an architect to iteratively test, experiment with, and communicate spatial ideas.

Course Website: https://soa.cmu.edu/courses (https://soa.cmu.edu/courses/)

48-104 Shop Skills

Fall
This course will introduce basic material assembly methods, and the use of shop machinery, hand and power tools. It prepares students to participate in a wide range of subsequent building and fabrication projects. We will aim to build confidence and safe work habits while demystifying the interactions between tools and physical materials.

Course Website: https://soa.cmu.edu/courses (https://soa.cmu.edu/courses/)

48-105 Architecture Design Studio: Poiesis Studio 2

Spring: 15 units
As the second studio within the Poiesis Sequence, this studio will nurture a way of making and thinking in design that aims to cultivate the practice of architecture as an act of creative citizenship. By building an affinity for an approach linking the cross-cultural study of how people perceive and manipulate their environments can push a multimodal understanding of architecture and urban design. We will use a multi-disciplinary approach to become detectives interrogating the contemporary and historical tissue of Pittsburgh through the occupations and working lives, therefore elevating ordinary folks and trades that had and continues to foster the fabric of the city. Grasping the multi-faceted changing environment, this studio will use architectural tools as a base of inquiry to speculate and allow us to transform the way we view our world through multiscale multisystemic perspectives. The structure of the studio will follow one cohesive research driven design project that will explore narrative modalities, by using critical cartography, archival research, storytelling, programming adjacencies and tectonic exploration as a method to produce a hybrid shop-house focused on the historical trades of Pittsburgh. Students in the sequence will be introduced to critical proficiencies, learn new techniques of representation, adapt rigorous illustration and animation tools in the production of a dwelling project that is rooted in its urban fabric.
Prerequisite: 48-100 Min. grade C

48-111 Exploring Pittsburgh

Spring: 3 units
The city of Pittsburgh is at once your (permanent or temporary) home and the site of many of your studio projects. In this class you will start exploring Pittsburgh - as built environment in which your work might be situated, as cultural context you need to interpret, and as creative material for your own work. You will learn some of Pittsburgh's urban history, looking at phases of physical growth and dramatic change over time. You will take walks, do site visits and sharpen your observation skills. You will critically engage with some of the evidence. You will start to read cities as complex and layered, shaped by invisible forces as much as by visible ones.

48-112 Digital Fabrication Skills

Spring: 2 units
"The formal qualities explored by designers today necessitates the use of sophisticated tools with a combination of flexibility and precision. This course serves as an introduction to the type of equipment and methodologies utilized in architectural fabrication. Students will develop a basic understanding of the field to leverage these processes to explore and represent the complex nature of their designs. Through lectures and lab sessions, students will learn the affordances of the machines available in the DFAB Lab (Digital Fabrication Lab), how to prepare 3D CAD models in Rhino 3D for digital fabrication, and basic CAM (Computer Aided Manufacturing) programming. A series of projects, each highlighting an individual machine, will reinforce this technical knowledge while requiring students to rationalize their designs so their physical manifestations are informed by the techniques introduced."

48-116 Introduction to Building Performance

All Semesters: 3 units
This course will introduce fundamental concepts of building physics. The knowledge and skills obtained from this course can be applied to studio projects and beyond, improving building design and performance through standard methods of evaluation and simulation tools. Couse curriculum running concurrent with studio projects will aid students in further developing and guiding design decisions to incorporate fundamental concepts related to climate, energy, light, relationship to site, and occupant visual and thermal comfort. Students will develop a general understanding of, site analysis, building placement and amp; form as it relates to building performance, photometric principles to evaluate lighting conditions, thermodynamic principles, and heat transfer, building energy, renewable and embodied energy. Skills, tools, and knowledge base learned in this course with enable designers and architects to employ sustainable practices at all phases of design, leading to better performing buildings.
Prerequisites: 62-125 and 62-122 and 62-123 and 62-126

Course Website: https://soa.cmu.edu/courses (https://soa.cmu.edu/courses/)

48-120 Digital Media I

Fall: 6 units
IDM is a required course for all first year architecture students. The course introduces students to a wide range of digital methods and concepts available to architects for design, representation, and documentation. The coursework is directly coordinated with Studio assignments providing the students with the opportunity to master their digital skills in a meaningful manner. Due to the amount of content covered there is no single text for this course, but the course is supported by materials created by the instructor. IDM addresses topics such as digital image editing, vector illustration, HTML coding, and 3D modeling.

48-121 Drawing I

Fall: 6 units
Architects draw and build models for a variety of reasons: to record and reference; to analyze and reveal order, intent, and relationships; to speculate; and to visualize new propositions. The study of architecture requires the connection between the mind, the eye and the hand, so that the nature of ideas and their relationship to physical form can be investigated. The connection of the mind, hand and drawing skills requires considerable time and effort. This course introduces why architects use these forms of representation. Students are introduced to how to do basic academic research as well direct assignments that apply the fundamentals of freehand drawings and drafting techniques as it pertains to plans, sections, elevations and paraline drawing, analytical diagraming and model making.

48-125 Digital Media II

Spring: 6 units
IDM2 is a required course for all first year architecture students. This course is the continuation of IDM. IDM2 introduces students to measured drafting and the process of creating a construction drawing set. The coursework is directly coordinated with Studio assignments providing the students with the opportunity to master their digital skills in a meaningful manner. Due to the amount of content covered there is no single text for this course, but the course is supported by materials created by the instructor. IDM2 addresses topics such as digital drafting, construction drawings, advanced 3D modeling and HTML programming.
Prerequisite: 48-120

48-126 Drawing II

Spring: 6 units
Drawing and Appearance? is a traditional course in free-hand architectural drawing. Its central learning objective is building a capacity for visualizing three-dimensional space through the making of hand-made drawings. Two secondary objectives foster visual literacy: the ability to use line, tonal values and color to represent architectural space and the ability to use drawing to represent architectural proposals at various levels of abstraction Coursework includes free-hand and constructed perspective, shade and shadow projection, chiarroscurro drawing in colored pencil and color drawing in pastel. Work is submitted in three portfolio submissions of two weeks duration each. Coursework is built around exercises in the required course text: Drawing and Perceiving, John Wiley and Sons.

48-175 Descriptive Geometry

Spring: 9 units
Descriptive geometry deals with solving problems in three-dimensional geometry through working with two-dimensional planes using basic mechanical tools. Descriptive geometry deals with physical space, the kind that one is used to since birth. Things one can see around us have geometry and even things that one cannot see, also have geometry. All these things concern geometric objects almost always in relationshipsthat is, next to, above, below, intersecting with, occluding, hidden by and so onto one another that sometimes requires us to make sense of it allin other words, when we try to solve geometric problems albeit in architecture, engineering, or the sciences. In fact, descriptive geometry has proved itself to be practically useful; it has been one of the more important factors in the design of scientific apparatus, engineering systems and architectural structuresit is the basis of modern geometrical computing. Descriptive geometry is constructivemeaning, one uses conventional mechanical drawing tools: namely, compass, ruler, protractor, divider, triangles, etc., to construct solutions to geometric problems. This course specifically revolves around the historical techniques for manually solving three-dimensional geometry problems.

Course Website: http://soa.cmu.edu

48-200 Poiesis Studio 3: Architecture Biome and Climate

Fall: 18 units
By conceptually recognizing the built/natural environment as a complex web of interacting parts constantly exchanging energy and resources, we may learn to develop architecture that enriches the context from which it arises. In response, the Poiesis Studio 3 explores how architectural and landscape design can respond to a local biome and climate through passive design strategies. We highlight the use of precedent and the relevance of our changing climatic context in how architecture takes shape - how it develops its morphology. Through an iterative process students develop formal and programmatic organizations as field conditions, or aggregations that highlight the localized interconnectivity of buildings, bodies, and environment. These building and landscape morphologies redefine boundary conditions to promote a connection to the local biome. Their envelopes become mediators between interior and exterior, public and private, the social and the ecological. Working from the scale of the territory to that of the building enclosure our goal is to arrive at a sensorially rich, environmentally responsive, and resilient architecture.
Prerequisites: 48-105 Min. grade C and 48-100 and 62-122 and 62-125 and 62-104 and 48-025 and 62-123 and 62-126

Course Website: https://soa.cmu.edu/courses (https://soa.cmu.edu/courses/)

48-205 Architecture Options Studios

Spring: 18 units
The second year option studios offer varied design strategies through material, computational, chronopolitical, cultural and ecological lenses.
Prerequisite: 48-200

Course Website: http://soa.cmu.edu

48-215 Materials & Assembly

Spring: 9 units
This course introduces and examines the fundamentals between design intent and construction materials, and the science of materials (performance) and their assemblies. Learning how materials and techniques inform spatial and form making decisions will be a central theme for the semester. Lectures and discussions will focus on the meaning, aesthetics and techniques related to the use of materials and the process of construction. A basic understanding of essential, well-known systems of building construction will be our base line. Discussions and case studies of contemporary systems that extend, experiment with and question these known systems will introduce you to the great depth to which this basic knowledge can lead you. Joint assignments with the design studio will provide you with an opportunity for an in-depth exploration of these fundamentals of construction through a direct application and synthesis of this new knowledge to your studio project.
Prerequisite: 48-100

Course Website: https://soa.cmu.edu/courses (https://soa.cmu.edu/courses/)

48-217 Structures

Spring: 9 units
Structures is a required course taught in the second year. It is a successor course to Statics, complementing that previous course by emphasizing structural member design in wood, steel, and reinforced concrete; spatial synthesis of hierarchical one-way systems for gravity load; structural types for lateral load including braced frames, shear walls, and rigid frames; introduction to geometric structures such as cable nets, domes, shells, and air-supported structures.

48-222 Explorations in Craft: Soft Forms, Stable Structures

Fall and Spring: 9 units
Softness is an evocative quality in architecture, but how do we "find" and then fabricate those elusive forms? How do we manipulate materials with control when the forms we seek, or their own structural makeup may lack it? When do we follow the material and when do we control it? This course is focused on physical model making of soft forms. It offers a series of encounters with material specificity, including textile, metal, and plastic materials, and the techniques used in transforming 2D patterns to 3D forms. Demonstrations, and workshops will inform material qualities, their formal affordances, and structural stability. Design and application of cutting and sewing patterns, bending jigs and casting molds will introduce the planning required to facilitate thoughtful crafting. The methods we work with are intended to open possibilities and refine skills for future making, ranging from quick form finding strategies to techniques for execution with precision. Note: A materials fee will cover workshop costs.

48-234 Introduction to Structures

All Semesters: 3 units
This course introduces structural systems and the materials and elements that make up those systems. Students will study historical and contemporary examples of bridges, long-span roofs, and tall buildings from technical, social, and symbolic perspectives. Through these built works, students will become familiar with structural engineering terminology and the behavior of different structural systems. They will also learn how materials, construction, and non-technical factors influence structural form. Additionally, students will evaluate the aesthetics of large-scale structures and discuss the relationship between engineers and architects. As they learn about structures, students will develop their problem solving skills and ability to communicate ideas by practicing using equations, drawing, and writing.
Prerequisite: 48-105

48-240 History of World Architecture, I

Spring: 9 units
This survey cuts a broad swath through time, geography and cultures, surveying critical episodes in the built environment of Europe, the Middle East, Asia, Africa, and the Americas from ancient times through the nineteenth century. Reflecting the inseparable relation between building and human needs, this course is not only a history of architecture, but also a history through architecture. Over the semester, we will examine architecture as a form of cultural expression unique to its time and place. Through readings and lectures, we will study the ways that the design, use, meaning, and legacy of a building and its site was conditioned not only by the architect's will or the patron's desire, but also by a web of technological, religious, social, cultural, economic, and political factors of the time. There will be several exams over the course of the semester including during finals week.

Course Website: http://soa.cmu.edu

48-241 History of Modern Architecture

Fall: 9 units
This course investigates the global history of modern architecture and theory across the 20th century. We ask critical questions about the canon, the changing nature of history and theory, the biases embedded in terms like "modernism," "progress," and "Non-Western," and the deep legacies of colonialism, globalization, extractivism, and capitalism in which modern architecture so actively participated. The course loosely works backward in time to explore major movements and monuments of the Euro-American avant-garde and so-called "heroes" of modernism, but also diverse responses to modernity, including popular, tropical, vernacular, indigenous, and even anti-architecture around the world, including increasingly the Global South. The course content changes slightly every year to acknowledge the evolving understanding of the subject, but also to keep up with changes in architectural education, the discipline of architectural history, and professional practice, as well as changes in global culture, social context, and our student aspirations.

Course Website: http://soa.cmu.edu

48-250 Urbanism and the Social Production of Space

Fall: 9 units
The course introduces contemporary urbanism, offering a comprehensive exploration of how cities and urban systems are made, remade, and even unmade. It approaches contemporary urbanism through urban theory, research, and practice to investigate the relationship between a set of intentions and consequences. It reflects the multidimensional nature of the externalities that determine the complex processes of urbanization and draws discussions on the fields of architecture, planning, landscape architecture, and social science. With a focus on physical, social, environmental, technological, political, and economic forces that influence city-making and urban life, this course analyzes various types of urban issues and phenomena, exploring through the questions of aesthetics, power, equity, and sustainability measures. In doing so, the course offers an understanding of the challenges of the 21st century, spanning from architecture to the city to planetary, and equips students with both conceptual and practical frameworks to observe, document, and analyze diverse urban milieus.

48-300 Architecture Design Studio: Praxis Studio 1

Fall: 18 units
Typically, we do site research and then design something for that site. However, this is a studio where the design research part of the semester will become the project itself. We're going to do site research and correlate it with the information we can find. We're going to make unconventional models and experiment with how we construct a network of sites through sets of relationships, linguistic, computational, and visual descriptions. In principle, we're going to think critically about how we construct the identity of a place through its cultural, social, and ecological systems, and develop procedures for doing so. We will investigate Pittsburgh as a collective site. Over the course of the semester, we will develop a "necklace" or circuit of sites that addressing Event, Housing and Infrastructure. The Steel Necklace will be a composite of these three different architectural/urban interventions to address the cultural, social and ecological issues of Pittsburgh. As the urban condition is a network of shared expressions, lived experiences and relationships, our studio will be a collaborative studio exchanging and intermixing projects. Students will detail into the collective network developing in high resolution a housing component relative to infrastructure and event spatial interventions.
Prerequisites: 48-215 and 48-200 Min. grade C and 48-205 Min. grade C and 48-116 and 62-275 and 62-225

Course Website: https://soa.cmu.edu/courses (https://soa.cmu.edu/courses/)

48-305 Architecture Design Studio: Praxis Studio 2

Spring: 18 units
This studio introduces integrated architectural design as the synthesis of disparate elements, demands, and desires. It situates architecture as a technological, cultural, and environmental process that is inherently contingent and entangled, yet tethered to a historical project of autonomy. It is within the contested space between these two notions of architecture that the studio operates. The studio sets out alternatives to extractive practices and introduces students to bio-based material practices and computationally facilitated methods of manufacturing and construction. While the studio directs attention to concerns of building, such as context, building systems, program, and regulatory constraints, it challenges students to situate design as a Project that engages contemporary discourse and ecological imperatives to explore emerging aesthetics, spatial organizations, and materializations. Our discussions and your work this semester will be guided by the following overarching questions: What is architecture's capacity to facilitate civic exchange/life in America today? How might we understand public space today? What are the public spaces, rooms, and interiors of the city in an era of increasing virtuality and privatization of public space? How do building typologies evolve and transform in response to technological and cultural shifts? How can architecture support and reveal the fluid and diverse needs of a community? How might a material-first, carbon-aware approach infuse the design process with greater material specificity and productive constraints?
Prerequisite: 48-300

Course Website: http://soa.cmu.edu

48-308 Reading and Writing Architecture

All Semesters: 9 units
As readers and learners, we consume lots of writing about architecture: articles appear in magazines, convincing and polished, finished products for which we struggle to imagine the process. We seldom pause to reflect on how that writing is produced, much less on how we could make writing a tool that works for us. In this collaborative, hands-on class we will work to demystify the process of writing in all its messiness and to highlight its iterative nature. We will explore how various genres of writing work and how architects can use them effectively, not only to communicate with audiences of all kinds but also to explore their own creative ideas. We will read writing about architecture by a number of different voices - architects, critics, historians, journalists, and activists. We will discover from their own approaches to writing what might work for us. We will experiment with writing and editing and explore how text, images and layout may come together to create a cohesive communication strategy. We will focus on becoming sophisticated as consumers and producers of written communication as we are for visual media.

48-310 Bizarre Details: stories of the ordinary, the uncanny, and the archit

Fall and Spring: 9 units
This design research course explores the current developments in hybrid, multi-platform design and communication mediums to prototype new ways of creative storytelling in architecture, visual development, and concept design. Research methods around oral storytelling, ethno-ecology, radical mapping, and the children's book can allow for the exploration of subjects in ways not available to typical architectural and urban research conventions. Throughout the Fall '23 Term designers will be tasked to use Pittsburgh, PA as a laboratory to develop a research project, from initial concept to an extensive script, including design elements, character development, as well as an urban critique of the city. Frameworks around composition, color, mapping, modeling, the parallel projection, and techniques in painting that are used in architecture, visual development, and concept design will ask how storylines translate and transform in the creation of a comprehensive project using industry techniques. To curate the explorations, we will explore innovative ideas in visual storytelling using techniques of interactivity in children's book design, experimenting with new forms of narrative strategies. The experimentations will result in a final exhibition at the end of Fall 2023.

48-313 New Pedogogies

Spring: 9 units
No course description provided.

48-314 New Pedagogies

Fall and Spring: 9 units
New Pedagogies are courses offered by new and visiting faculty (sections A-D). Please visit https://soa.cmu.edu/courses for complete course descriptions.

48-315 Environmental Systems: Climate & Energy in Buildings

Fall: 9 units
Our commitment to designing net zero energy and indeed carbon positive buildings and communities is critical to environment equity and the UN Sustainable Development Goals. This course introduces architectural design responses for energy conservation and natural conditioning, human comfort, and the site-specific dynamics of climate. The state of the art in building energy conservation and passive heating and cooling technologies will be presented in lectures and supported by readings and assignments. An overview of energy flows in buildings and energy design standards is illustrated by lectures on building energy conservation successes, and emerging demands for a broader definition of sustainability. To understand the significance of architectural design decision-making on energy consumption and comfort, students will compile a professional energy consultant's report for a residential-scale building, designing the most viable energy conservation retrofit measures for their client from siting, massing, organization, enclosure detailing, opening control, to passive system integration and management.

Course Website: https://soa.cmu.edu/courses (https://soa.cmu.edu/courses/)

48-317 The Chair

All Semesters: 9 units
Making entitles to an intimate connection with the site, native atmosphere, building components, and their assemblies, where a designer/maker can operate at local - regional and global levels comprising all the building systems. This sedulous process takes very closer to the materials where a designer/ maker can gather insights into material behavior (both mechanical and visual) and is better placed to alter the effects of architecture through its materials and generating processes. The same can be applied to chair making. The chair no longer remains a chair, as the making process makes it a ground of experimentation and learning to shape the material into the desired object. The reaction with the matter is no more inert, as it tends to provide feedback to the maker while shaping it. This immersive process of learning by doing in entirety, aids students, in improvising their thought process, the judgment of material behavior, use of the right tool to save material, and developing novel ideas for production and assembly. Prototyping and making largely help develop the understanding concept of joinery/material behavior, and properties in relation to form. The exercise allows understanding chair as a piece of furniture, the manner of making that gives qualities to an abstract design or idea, the know-how of handling material, emergence of tacit knowledge in the maker, and tolerance and feedback from the material.

48-318 Discourse and Praxis in the Climate Emergency

Spring
This course engages with emergent modes of architectural thinking and praxis in the climate emergency. If buildings consume vast resources and are embedded in extractive systems of material and labor, how can discourse be deployed to consider other forms of praxis?

48-324 Structural Design 1: Form and Forces

Fall and Spring: 6 units
This course introduces fundamental concepts of static equilibrium and stability of structures. In contrast to conventional methods of learning structures that are based on numerical calculation and analysis of stresses in materials, this course explores a new geometric approach to understanding the relationship between form and forces of structures through graphic statics, a graphical method of visualizing, designing and analyzing equilibrium. By using geometry as the common language between architecture and structure, the students will explore new ways of shaping structural form by drawing and manipulating the geometry of forces. Through a series of lab exercises, the students will learn how to construct form and force diagrams used in graphic statics, and learn how the behavior of basic structural systems can be understood through such representations. The lab exercises are complemented by group design projects, where the students have the opportunity to apply the concepts and principles learned in the lab to design and build physical structural models that will be loaded to failure. No prior knowledge is required for this course. Structural Design 1 is the first of three courses of the Structural Design curriculum offered at Carnegie Mellon Architecture.
Prerequisite: 48-205

Course Website: http://soa.cmu.edu

48-328 Detailing Architecture

Spring: 9 units
"This course examines the role of the architectural detail in the formation/ thematic development of a work of architecture and how the detail reinforces the theoretical position of the architect.
Prerequisite: 48-205

Course Website: http://soa.cmu.edu

48-332 Teaching and Learning

Intermittent: 6 units
In this course, students will learn about effective strategies for teaching architecture and the built environment. Topics include the cognitive differences between novices and experts, instructional techniques, and goal alignment. As part of the coursework, each student will implement these teaching strategies to design and teach a lesson. Elements of developmental psychology, learning theories, and classroom practices will inform the architectural education lesson. Teaching and learning techniques can be generalized for communication with clients, practice, and the community.

48-336 Architecture and Agency

All Semesters: 9 units
If buildings consume vast resources and are often embedded in extractive systems of material and labor, how can the agency of architecture be deployed to consider other forms of thinking and praxis? What tactics, strategies, manifestos, and actions can architects deploy to resist, upend, destabilize or reinvent normative mechanisms of architectural production? How do such practices seek new modes of conceiving the architectural project and its concomitant processes; radically reinvent the brief, site, program, material or tectonic capabilities? This course will consider agency simultaneously through historical and contemporary forms of praxis as well as theories that inform them.

Course Website: http://soa.cmu.edu

48-338 European Cities in the XIX Century: Planning, Architecture, Preservation

All Semesters: 9 units
The history of the main cities of Europe during the XIX century is a history of change and transformation. The physical environment and the political, financial and administrative structures adapt to the needs of new masses of population and to the challenges of metropolitan life. In some cases, cities even acquire new representative functions, as they become a national capital. This course traditionally offers an overview of the urban culture of XIX century Europe, reconstructing aspects of the broader historical context and then focusing on reading the effects of the XIX century transformations on the physical appearance, structures and image of present-day European cities, such as Paris, London, Berlin, Barcelona, Vienna and Rome. This semester we will add to this analysis, acquired by learning and applying a set of essential questions about XIX century urban transformations, a second look at the image of the city - the issue of how the city is represented and described in the various moments of its Nineteenth century transformation (from historical maps, to paintings, from postcards to literary descriptions). We will try to consider its changing visual representation and the different perception of its character and peculiarities over time, finally discussing how the Nineteenth century image of each city still affects how it is viewed today. We will rely, along with the usual reading materials (articles, book excerpts) also on visual documentation, such as photography and film. The course is based on lectures and discussions and requires personal elaboration, as well as a fair amount of reading and writing.
Prerequisite: 48-240

48-339 IDeATe: Making Things Interactive

Spring: 12 units
In this hands-on design-build class you will learn the skills to embed sensors and actuators (light, sound, touch, motion, etc.) into everyday things (and places etc.) and to program their interactive behavior using a microcontroller. You'll also dive into the fields of VR/AR/MR and experiment with combining these disciplines with physical computing. Through weekly exercises and a term project the class will introduce basic analog electronics, microcontroller programming, projection mapping and virtual reality; as well as exploration into using kinetics and materials to make the things you design perform. Emphasis will be on creating innovative experiences. The graduate edition of this course will require additional work including a paper that can be submitted to a peer-reviewed interaction design conference such as CHI, UIST, or TEI. Students from all disciplines are welcome: but please note that the class demands that you master technical material. Experience in at least one of: programming, electronics, or physical fabrication is strongly recommended.(Participants will provide their own supplies and materials.)
Prerequisites: 60-223 or 16-223

Course Website: http://soa.cmu.edu

48-340 Modern Architecture and Theory 1900-1945

Intermittent: 9 units
This architectural history lecture course surveys the modern buildings and literature of the first half of the twentieth century, focusing primarily on Europe but extending also to non-western countries. We begin with a look at the "crisis of modernity" that plagued most of western civilization in the late 19th-century, and then focus on the major movements of both the avant-garde and other responses to modernity from 1900-1945. The course includes lectures, readings, and discussions about a broad range of issues, including 1) Formal tendencies; 2) Theoretical issues; 3) National traditions; 4) Biographical sketches; 5) Significant technologies and materials; 6) Political motivations; 7) Social and amp; cultural influences. Emphasis will be placed on the relationship of buildings to the more general cultural, intellectual, and historical circumstances in which they were created, especially the important manifestoes, theoretical and critical writings that so determined the project of modern architecture. Work for the course involves extensive reading and a major research paper.
Prerequisite: 48-240

48-341 Expression in Architecture

Intermittent: 9 units
This architectural history seminar will explore expression in architecture in its many forms, particularly in written works of architectural theory through the ages. We start with the premise that architecture is not merely pragmatic, technical, or functional: it can express or communicate like a language, it can represent and inspire like many of the arts, it can shape behavior and emote, it can trigger memories, emotions, or meanings. As Isozaki put it: ?Architecture is a machine for the production of meaning.? We?ll investigate many ways that architects have theorized the design process, as well as the forms, materials, and contexts of architecture, to express a myriad of ideas and sensibilities. We?ll also look at the ways that buildings can communicate and have meaning, often beyond the intent of the architect, and usually changing over time. Some of the topics to be explored include the classical orders, gothic geometry and mystical light, the theatrical space of the Baroque, architecture parlante, character, and style in the Enlightenment, tectonics as structural expression, political architecture and morality, the aesthetics of functionalism, Expressionism, key terms such as ornament, representation, linguistics, and semiotics, as well as more recent theoretical constructs such as embodiment, materiality, atmosphere, and affect. The work of the seminar will include intensive weekly readings, especially of primary sources by the architects seeking to express ideas, weekly presentations and discussions about the sources, and a term paper on an important theory of expression in architecture of your choice.
Prerequisite: 48-240

48-348 Architectural History of Mexico & Guatemala

Intermittent: 9 units
Despite the leveling forces of mass culture and globalization, the geographic and social diversity of the U.S. has created distinctive regional mosaics of landscape and architecture. Say New England and images of English Pilgrims, town greens with white framed churches, and industrial mill villages may come to mind. The Southwest conjures different images, perhaps of adobe pueblos, Spanish friars, arid ranches, and the color turquoise. The built environment of the Midwest, the California coast, the Mississippi Delta, and many places in between reflect particular regional identities that have been both unconsciously and consciously created over time. This course examines the historical development of regional patterns in the American built environment. It investigates how and why a regions architectural identity evolved in the ways that it did. To what degree is place something to respond to, to interact with, and to what degree is place something that is created? Our focus will be primarily pre-20th century when the forces of vernacular traditions were stronger, we will also examine more recent trends of regionalism as an aesthetic choice and a theoretical stance.
Prerequisite: 48-240

48-350 Postwar Modern Architecture and Theory

Intermittent: 9 units
This architectural history lecture course surveys the modern buildings and architectural theory of the post-World War II period. It begins with the cataclysm of WWII and the fundamental shifts it caused on the conception of modernism, technology, cities, and geo-politics. It proceeds to investigate themes such as rebuilding and reconstruction, grand modern masters such as Mies, Kahn, and Le Corbusier, the fascination with technology, megastructures and utopian thought, the need for monumentality, meaning, and regional identity, and the dissemination of modernism from corporate America to the third world. It ends with the rupture in modernism associated with the social revolutions and the rise of a post-modern architecture in the late 1960s and early 1970s. The course includes lectures, readings, and discussions to define the unique character of the postwar period, as modernism both reigned supreme, and began to be questioned. Emphasis will be placed on the relationship of buildings to the more general cultural, intellectual, and historical circumstances in which they were created. Special attention will be devoted throughout the course to the important manifestoes, theoretical and critical writings that so determined the project of modern architecture. Work for the course involves extensive reading, preparing for class discussions, and a major research paper.
Prerequisites: 48-240 or 48-241

48-355 Perspective

Intermittent: 9 units
This freehand drawing course considers perspective from three understandings of perceptual psychology. Part 1, built on the pedagogy of Kimon Nicolaides, aligns with the Transactionalist understanding of perception. It considers perspective as discovered truth. Part 2 builds on the early work of perceptual psychologist, J.J. Gibson, and aligns with the Ecological position of Gibson and his followers. It considers perspective as an absolute truth of the visual field. Part 3, aligning implicitly with Gestalt psychology, treats perspective as an imposed schema. The course concludes with a final project built around the student's interest.
Prerequisite: 62-126

48-356 Color Drawing

Intermittent: 9 units
48-356 Color Drawing provides practice in the use of color to depict architectural surroundings. Following preliminary exercises using pastels, watercolor is used for most of the course. A central objective is that by the end of the course, students will have good judgement in evaluating color hue, value, and temperature and gained confidence in use of watercolor. Coursework assumes some knowledge of linear perspective. Work consists of in-class exercises and weekend assignments built on these. Students can expect to spend up to 6 hours of work per weekend.
Prerequisites: (48-121 and 48-126) or (48-130 and 48-135) or (62-126 and 62-125) or (48-120 and 48-125)

Course Website: https://soa.cmu.edu/courses (https://soa.cmu.edu/courses/)

48-359 Special Topics: Design Build / Building Systems

All Semesters: 9 units
In this studio we will consider Thoreau's essayso much of it about his own design/build experiencein today's context. Collectively, we will design a cabin to meet the high standards of sustainability set by Eden Hall. After a round of prototyping, testing, and design development, the studio will create a set of construction documents and shop drawings. Covid and funding allowing, we will begin building the cabin at mid-term, with construction continuing into the summer or fall as required. This studio has a nine credit co-requisite, 48-358 Cabin Building Systems, which is also open to CEE students. Its focus will be on the building systems for the cabin that is being developed in the parallel studio. Topics include energy performance (e.g. production, renewable energy systems, passive and active ways to achieve efficiency, and modeling); integrated structural and engineering systems (e.g. building envelope, water treatment and management, heating and cooling systems, and electrical and lighting systems; and sensing for monitoring and control. The class will have a team-based format that is hands-on and lab-oriented rather than a seminar structure, and it will contribute directly to the build part of the studio.

48-367 Material Histories

All Semesters: 9 units
Materials affect the way we engage with a building and carry cultural meanings connected with complex histories, deeply and at times messily intertwined with the social, political and ecological context. In this seminar we will look at the history of the architecture of the last two centuries by following the thread of the history of materials. We will discuss the ways in which buildings of the past and the practice of architecture were affected by which materials were available, how they were produced, and the craft required to work them. We will reflect on how architects interpreted, manipulated, or added to those meanings through their own work. Materials' lifecycles and the networks of extraction, production, transportation, and reuse had an impact on the built environment in the past, just as they do today. We will learn from historical examples to assess the consequences of the choices we make as designers. Finally, we will critically engage with the presence of history as a layer of complexity embedded in the material itself - an effect that is compounded in the practice of reuse of materials with patina, marked from their past use.

48-368 Rediscovering Antiquity: Archaeology for Architects

Spring: 9 units
The course follows the intertwined histories of architecture and archaeology from the mid-eighteenth to the early twentieth century, critically engaging with the outsized influence of classical antiquity on architectural theory and practice and its role of authority and model in the Western artistic and cultural debate. The traces of classical antiquity, buried in the Mediterranean and Middle Eastern landscape, retained part of their cultural significance over the centuries and became the object of a "rediscovery", almost a cultural obsession. Artists, travelers and architects filtered and re-interpreted the reality of ancient objects and places, conjuring up their own vision of the past and nourishing their own creative pursuits from a continuous dialogue with history. At the same time, new political agendas, new biases and new goals were associated with antiquity, influencing the way the past of the region was explored, how the finds were studied and exhibited in residences and Museums, and ultimately creating a stern competition to appropriate this legacy, with deep links to colonialism and imperialism. The ripple effects are still being felt today, for example in the discussion about the repatriation of cultural heritage. We will study the history of this moment to better understand the cultural vantage point that often influenced the fabric of our cities, presided over the creation of many of our cultural institutions and the buildings that represent them, and had a deep and lasting impact on the ideas about architecture and its relationship with history. This will help us grasp more clearly the impact of the "passage to the Modern" and some of the complex and still open issues it brought about.
Prerequisite: 48-205

48-369 Sustainable Architecture and Urbanism for the Gulf Region

Intermittent: 3 units
Ensuring a sustainable built environment in Qatar is critical to sustainable Gulf Region and indeed a sustainable world. The quality of our architecture and urban design can significantly address the challenges of heat, water, energy, mobility, material resources, waste, and health. This course is intended for non-architects to explore the potential of sustainable design for desert climates. Six weeks of explorations and presentations will introduce each student to: Climate analysis for Gulf Region countries and their 'twins' around the world; Green standards for desert climates with their embedded metrics (eg UNSDG, LEED, GreenStar, WELL); and Precedent as a precursor to innovation - a search for great sustainable examples across building types and land use. In-class and homework assignments will create a series of collaborative student slide shows each week. As possible, invited speakers and site visits will be pursued. The final week will be dedicated to a class perspective on the importance of the built environment for carbon and climate change, and student recommendations for building and infrastructure goals for a more sustainable Gulf region. CMU-Q graduates should be dedicated to a more sustainable built environment and understand the design changes needed for sustainability, the benefits to quality of life and to ecological sustainability. Every discipline is a catalyst and a stakeholder in our future - as client, as design/engineer, as consumer, as financier, as scientist.

48-371 City & Suburb: Housing in America after 1850

Fall and Spring: 9 units
This architectural history course examines the development of American house and housing choices during the period 1850-1975. A recurring picture of the "American Dream" has typically included the image of a single-family, detached dwelling set within its own green yard in the suburbs. However powerful and durable that image is, the history of house and home in America is actually a far more complex story with many different twists and turns. In the course we will look at both urban and suburban housing choices and cultures, ranging from single family detached dwellings to multi-unit housing, and across a social spectrum income, class, race, and gender. Through the use of occasional field trips, we will use Pittsburgh as a touchstone for understanding broader national trends in the history of American urban and suburban housing. The course is organized as a lecture course supplemented with field trips and discussions based on field trips and primary source readings. The additional time slot on Thursday afternoons will be used only when field trips are scheduled. Student work will include a research paper and several shorter written assignments throughout the semester.
Prerequisite: 48-240

48-373 Istanbul Constantinople. An Urban History

Fall and Spring: 9 units
A dynamic metropolitan area, with a burgeoning population and rapid urbanization, Istanbul is at the same time a finely woven tangle of historical layers. In this class we will introduce urban history and its methods as we focus on key moments of Istanbul's history. We will delve deeply into the city's powerful and at times competing historical narratives. We will trace the growth and transformation of the urban fabric, discussing Istanbul's role as imperial capital of the Romans, the Byzantines, the Ottomans, its changing fortunes in the twentieth century and the historical roots of the present-day world city. We will discuss cultural specificity and reactions to international models, the challenges of preservation and transformation of the urban fabric and the political making and re-making of its cultural identity. We will also take into account the power of this city to fascinate and inspire through the centuries - the imagined city as a layer of the physical one.
Prerequisite: 48-240

48-374 History of Architecture in the Islamic World- A Primer

Fall: 9 units
An introduction to the architecture of the lands where Islam spread over the centuries, this course aims to provide a basic understanding of major epochs and regional variations. We will learn the function and meaning of the most important building types, examine how these types changed over time to adapt to the needs of changing societies and consider influences and exchanges with other traditions. We will examine the historical context within which art and architecture developed and explore critically the lingering signs of those traditions in contemporary society.

Course Website: https://soa.cmu.edu/courses (https://soa.cmu.edu/courses/)

48-380 Constructing Value(s): Economies of Design

Spring: 6 units
This course explores the systems of economic, political, social, and regulatory forces driving the production of contemporary architectural projects. It critiques these systems, examines alternatives, and tests interventions in pursuit of value propositions outside of the bottom-line driven norms of late capitalism. What do design economies driven by equity, circularity, ecology, pluriversality look like? Through lecture and discussion, real world case studies in both for-profit and non-profit sectors, both locally and internationally, students explore the process of project development from multiple perspectives and gain insight into dynamics that determine if, how, and when projects are realized as well as relationships among various stakeholders, including architects, developers, and communities.

Course Website: http://soa.cmu.edu

48-381 Issues of Practice

Spring: 6 units
"This course explores the interdependence of contracts, drawings, specifications, and correspondence and introduces the concept of the Standard of Care. It addresses business development, staff training, and time management and introduces the economic, cultural, and political contexts in which architecture is created. To reflect the pedagogical priorities of the school, social justice related issues related to architecture will be examined. Students will engage with practitioners, consultants, constructors, and others who together form the design and construction team to learn the specific knowledge and skills the team members bring and to understand the importance of collaboration. They will study the effects of owner expectations and field conditions. Students will learn the value of, and path to, licensure, exploring NCARB's licensure path and Architectural Experience Program (AXP). The course describes alternative career paths that would allow students to use knowledge and creative skills gained in their time in the School of Architecture. The class will align with related courses to provide a comprehensive exploration into the broad profession of architecture and be taught in coordination with the students' concurrent architecture studios so that the students can consider their studio projects from a practitioner's business perspective."

Course Website: http://soa.cmu.edu

48-383 Ethics and Decision Making in Architecture

Intermittent: 6 units
This course investigates ethics for architecture and the built environment. Students will learn about ethics as a discipline, how to identify an ethical issue, and how one might work through an ethical problem. Frameworks will be presented with case studies for practice and discussion. On a macro scale, we will consider the entanglement of architecture with capital as well as sustainability and climate change. We will also touch upon day-to-day concerns regarding safety, zoning, contracts, material selection, internet of things and workplace discrimination. Reading responses and class discussions are the primary format for learning. Each student will also conduct an ethical assessment of one of their studio projects. Non-architects are welcome.

Course Website: http://soa.cmu.edu

48-386 Portfolio & Resume Preparation (UG)

All Semesters: 3 units
No course description provided.

48-390 Physical Computing Studio

Spring: 10 units
This collaborative studio course will allow interdisciplinary teams to develop wearables with a focus on assistive technology. The ubiquitous nature of mobile devices coupled with low-cost and easily integrated sensors and actuators make this a good time to approach real problems for a range of users from the physically disabled to athletes. Teams will learn skills in hardware, software, fabrication, and design communication in order to effectively develop and share their ideas.
Prerequisites: 60-223 Min. grade C or 16-223 Min. grade C

Course Website: http://ideate.cmu.edu/

48-400 Architecture Design Studio: Praxis Studio 3

Fall: 18 units
This studio is the capstone of your undergraduate education and is an opportunity for you to integrate the various technical aspects of your professional degree to date. Each student will have the opportunity to select from one of three proposed building typologies and project scales. As a requirement of this studio, students will participate in student teams developing each project to a high level of technical development. The objective of this studio is to go beyond the typical studio project and to demonstrate the necessary integration within the structural system, building envelope, environmental control systems and life safety system while providing the measurable outcomes of building performance as part of the design process (NAAB student criteria 6). Consultant engineers play an active role in the studio process providing expertise and discussions resembling professional practice. This semester the three studio instructors will be Professors Gerard Damiani, Erica Cochran Hameen and Stephen Lee.
Prerequisite: 48-305 Min. grade C

Course Website: https://soa.cmu.edu/courses (https://soa.cmu.edu/courses/)

48-405 Advanced Synthesis Options Studio II

Spring: 18 units
Having proven competency in the spectrum of skills determined necessary for tomorrow's architect during the first three years of the program, students in their fourth and fifth year are permitted to select from a variety of studio options, each providing the opportunity to build upon or augment some of those skills with new or more nuanced perspectives. All advanced synthesis studios are open to both years, the vertical integration offering enhanced learning opportunities.The content and focus of each studio is governed by faculty interests, which run the spectrum of architectural pursuits, ranging in scale from the design of a piece of furniture to a city and in approach from a comprehensive and complex building program to a critically-driven speculation. They may also be interdisciplinary in nature, taking advantage of the unique juxtapositions made possible at Carnegie Mellon.
Prerequisites: 48-412 and 48-400

48-408 Co-designing an Indigenous Biodiversity Knowledge Learning Space for the Vertica

Spring: 12 units
This is an advanced comprehensive Critical Practice track studio, with one large, complex, semester-long building design project. The studio pedagogy is based on the parallel development of a real project currently being planned, a new performance space for the San Francisco Symphony; it is on the same site and with the same goals and constraints as the actual project. The participation of clients, the professional design team working on these projects, and users is incorporated in the studio? exploration and design process, culminating in review presentations to the client and project team and publication of the body of work. This studio is also a key component of Carnegie Mellon University?s Theater Architecture Program, and is offered annually to fourth- and fifth-year students in the Bachelor of Architecture program. The co-Requisite, Theater Architecture Seminar (48:408), provides in-depth research in the typology, analysis of precedents, and the programming and planning of the studio project.

48-409 History and Future of Interaction Design

All Semesters: 9 units
The history of Interaction Design (IxD) is far richer than what is visible from today's tech. Many great ideas have been mangled and even lost. By making prototypes inspired by this history, we reach new insights and illuminate a future of promises and perils. In this course you begin by mining historical IxD innovations by building prototypes in a modern vernacular that forefront lost contributions. In 3 sprints you render a powerful but lost essence in the form of a concept storyboard, video, or clickable prototype. Thus you explore the History of IxD. To explore the Future of IxD, you are invited to invent itby developing your own vision in the design of a final project prototype with the focus and scope that you control. Coursework is partly historical review and largely designing and producing prototypes in a studio setting, especially suited for backgrounds in interaction design, computational design, responsive architecture, media, or coding.

48-410 Advanced Synthesis Options Studio II

Spring: 18 units
The vertically-integrated advanced studios encourage interdisciplinary collaboration from arts, technology, research and design. They range from large scale urban and ecological projects, to detailed investigations of materials, and fabrication strategies.
Prerequisite: 48-305 Min. grade C

48-425 EX-CHANGE: Exhibition & Publication in Practice

Spring: 3 units
Are you interested in exploring exhibition design, curating, or publishing as part of your practice? This course will give you hands-on experience, inviting you into the process of planning, designing, and curating the 2023 EX-CHANGE, an exhibition and publication that will be launched at the School of Architecture in fall 2023. EX-CHANGE is the School of Architecture's annual exhibition and publication celebrating student work from first year to PhD. Inaugurated in 2017, EX-CHANGE represents an ongoing opportunity to shine new light on the SoA's programs and to position the work within larger questions of research and practice. Students will work alongside EX-CHANGE director Sarah Rafson and the professional design team who have been selected for the 2023 EX-CHANGE to get a glimpse into editorial and curatorial practice. This is an opportunity to play a role in shaping an exciting school-wide event.

48-432 Environment II: Design Integration of Active Building Systems

Fall: 9 units
If there is a benefit to recent global and national upheavals, it may be that we are even more keenly aware of the importance of equity, of social justice, and a more sustainable future. That sustainability must cover the full range of the UN Sustainable Development Goals and your understanding of how you can contribute to a better future through design in the built environment is a primary goal of this course. High performance buildings are achieved with designs that effectively integrate passive and active systems. This course focuses on active systems in commercial buildings and their integration with passive design elements you've studied previously: envelope, ventilation and lighting. We also consider building codes that address outside air requirements for ventilation, and for energy and water efficiency, and discuss where related US building codes lead or lag in promoting exceptional building performance. Environmental sustainability and buildings within the United States receive the greatest emphasis in our work, but we also consider how performance definitions may change where resources like energy or water are limited or unavailable. The active systems covered include lighting, ventilation, heating/cooling, water distribution and water heating, and renewable energy production and amp; storage.

Course Website: https://soa.cmu.edu/courses (https://soa.cmu.edu/courses/)

48-435 Modern Mexico & Guatemala: 19th-21st Century Architecture

Fall and Spring: 9 units
This course focuses on the 20th-century architectural and urban history of Mexico City. We will study both the high-style design vanguards and the vernacular built environment. Topics include the 19th-century ruralscapes and cityscapes that sprouted the seeds of the 1910 Mexican Revolution, the role of arts and architecture in a post-revolutionary world, changing ideas about art and architecture within a globalizing world of international influences, projects oriented toward the elites including upper-class suburbs by prominent architects, projects directed towards the working classes including informal settlements by unnamed "squatters", and the cascading environmental challenges that have pushed to the forefront of the 21st century. A recurring theme of the course will be the various and competing architectural expressions of Mexican identity and #8212; Mexicanidad. Non-majors are welcome.

Course Website: http://soa.cmu.edu

48-438 Modern Mexico & Guatemala: 19th-21st Century Architecture

All Semesters: 9 units
This course examines the architectural history of modern Mexico and Guatemala, with an emphasis on the 20th century, but drawing on the 19th and 21st centuries as well. We will use architecture as a lens through which we study how both the high-style design vanguards and the vernacular built environment were responses to forces such as industrial modernization, urban growth, economic fluctuation, international relationships, political and social revolution, indigenous discrimination, genocide, and cultural regeneration. Throughout the course we will look at the countries' urban and rural architectural evolution as explicit and implicit expressions of identity (Mexicanidad or Guatemalidad).

48-442 History of Asian Architecture

Intermittent: 9 units
This course is intended to serve as an introduction to the evolution of urban spaces and the function of the architecture in South Asia, China, Korea and Japan. It is organized chronologically and will examine the impact of indigenous philosophical principles on the organization of villages, capital cities, and religious centers. The course will begin in the Indus Valley where complex urban planning along with public and private architecture flourished from 2600-1900 BCE. We will examine South Asian Hindu and Buddhist cave monasteries as well as freestanding Hindu temples and identify the salient architectural forms that identify each type. We will then move to China where the earliest villages were arranged according to ideas about nature and the organizing system of fengshui. By the earliest Chinese dynastic period, urban planning and building placement were beginning to be codified according to Confucian and Daoist ideals. Later Chinese imperial centers were consciously designed according to Confucian regularity and hierarchy in order to make visual statements about power. We will then move to consider urban organization and Buddhist temples in China, Korea to Japan where South Asian and Eurasian models were adopted and adapted. The examination of the Japanese warrior culture will include castles, new ideas in residential architecture, the Pleasure Quarters, and retirement villas. Contemporary architecture will be addressed through individual and group projects that will investigate specific structures and situate the buildings within the cultural and historic circumstances that led to their creation.
Prerequisite: 48-240

Course Website: http://soa.cmu.edu

48-448 History of Sustainable Architecture

Intermittent: 9 units
The History of Sustainable Architecture investigates themes of nature, ecology, pollution and conservation in the built environment and visual arts. The term ?sustainable architecture? is a comparatively recent one, arising in reaction to the destructive and toxic nature of the industrial era and its strident ambassador, Modern architecture. Yet, an esthetic and philosophical view of harmony with nature accompanies many forms of historical human activity in the built environment. Similarly, issues of waste removal, mechanical systems and natural materials that characterize current concerns have illustrative historical roots in numerous civilizations going back centuries and even millennia in pre-Industrial or non-industrial cultures. This course will engage texts and examples relating not simply architecture, landscape and urban history, but also art, philosophy and popular culture as a means to understand the many precedents for today?s interest in sustainable architecture and planning. The course will examine texts and works by figures including Vitruvius, Pliny, Leon Battista Alberti, Thomas Cole, Frederic Law Olmsted, Buckminster Fuller, Reyner Banham, Ebenezer Howard, Hassan Fathy, Bernard Rudofsky, Norman Foster, Robert Smithson, Andy Goldsworthy and more. Students will be encouraged to apply principles from the class to understanding and execution of work in their own discipline.

48-452 Real Estate Design and Development

Fall: 6 units
This course will introduce the Real Estate development process and explore the interdependence of development drivers and the design process. Classroom learning, exercises and guest-lectures will introduce students to the concepts of market and financial analysis, as well as the basic techniques of budgeting, proforma development, and valuation. Parallel to this investigation, students will evaluate real world developments and interface with the development professionals that executed them to learn how development drivers shaped the development process and decision making. Students will study how market demand, tenant requirements, site constraints, and available capital affect feasibility, and through this the ultimate design solution. The semester's effort culminates in the execution of a mini-development project. Students will work in teams to complete a basic market analysis, program evaluation, schematic design, construction and development cost estimate, proforma analysis, and a determination of financial feasibility. Development practitioners will interface with student teams during this mini-project to offer "real world" guidance on student schematic designs and feasibility analysis.
Prerequisite: 48-305

48-453 Urban Design Methods

Fall: 6 units
This undergraduate lecture course introduces urban design history, theory and methods. It is a required supporting course for the Urban Laboratory design studio, and similarly examines urban design at multiple scales: city form and networks, neighborhoods and block structures, streets, public spaces, and urban building typologies. Key issues introduced include the emergence and evolution of urban design as a discipline, economic, social and political factors affecting the contemporary city, and environmental sustainability at the urban scale. A wide variety of cities, projects, proposals and methodologies are examined. Assignments include readings from seminal texts, quizzes, and a final examination.
Prerequisite: 48-305

48-454 Futures of the City/Cities of the Future

Intermittent: 9 units
If all design can be read as attempts to predict and to shape the future, then no one looks further into the future than the urban designer and the urban planner. The work in which they are involved often does not materialize in their lifetimes; in fact, the duration of the projects are so long twenty, thirty, fifty and hundred year timeframes, it is more than likely that he or she will pass on before the project reaches fruition. The trouble with predicting the future is that it is so uncertain, so undecided, so unknowable. A brief look backwards reveals that we are not the first generation to consider the future. History is replete with predictions, some of which were actualized, the vast majority of which were not. Today's forecasts for tomorrow vary wildly. A handful of optimists view the future through rose colored glasses, whereby humanity is delivered to salvation via technological wonders and the widespread adoption of common social values. A larger group predicts the end of the world as we now know it, but even they cannot agree on the cause of our demise, with those arguing that climate change will kill us clashing with those convinced that we will be destroyed when robots achieve technological singularity. Shy of total extinction, however, any vision of the future requires designers, and will likely occur in urban (or formerly urban) locations. As of this decade, for the first time in history, more than half of the world's population, almost three and a half billion people, live in towns and cities. Estimates suggest that by 2030 this number will swell to almost five billion.
Prerequisite: 48-205

48-459 Material Simulacra

All Semesters: 9 units
This fabrication-based course interprets Jean Baudrillard's ideas of "panic-stricken production of the real and the referential, above and parallel to the panic of material production." Serial mold-generated surface studies activated by material properties, behavior, intuition, and expression ask how our perceptions of the real is mediated by language of the made artifact. Structured as the tripartite investigation: TheoryResearch-Craft, this seminar's pedagogy is centered on the cultural, historical, ethical, aesthetic and tectonic values of architectural materialism to arrive at an awareness of what a material conveys. Analog and digital techniques and simulations engage the technological and intellectual roles of the craftsperson.

Course Website: http://soa.cmu.edu

48-470 The Depth of Surface

Fall: 9 units
Lamination is the process of gluing wood together along the edge or face of a plank. There is unlimited variety in the ways to do this and to generate pattern in the process. This course will prescribe a few basic ways to laminate following standard rules of wood working and then introduce the possibilities of pattern generation. Generally lamination is unidirectional, however, in this class we will introduce ways to achieve cross directional patterning and the use of inlay to elaborate on the idea of patterning. Projects will be visual and sculptural statements. Their function will be limited and will not be furniture. Each exercise will present a series of basic wood working operations, which, when repeated and recombined will become products of compelling visual character. As visual idea statements you will be asked to experiment, invent and explore and take these standard operations in new directions. As visual idea statements the greatest clarity of vision will be achieved through careful construction.

48-473 Hand and Machine Joinery, New Directions

Fall: 9 units
In the Fall 2017 and Spring 2018 there will be some changes to the shop electives offered. First the Spring Furniture Design and Construction course # 48564 will no longer be offered because that content is incorporated within the Furniture Studio in the fall. Next, the two shop mini courses previously offered in the fall will each be expanded to become full electives, one in the fall and one in the spring. The prerequisite for both of these classes is documentable experience with the band saw, table saw (ripping and crosscut), drill press and the belt and disk sander. The Hand and Machine Joinery, New Directions, is scheduled Tuesday and Thursday mornings 10:30 am to 11:50 in the spring 2018, and will be a 9 unit elective running the entire semester. The elective will focus on building a free standing (or hung) cabinet with doors. If enrolled students have taken the Exploring Pattern course in the fall the doors made in that class will be mounted on the cabinet. If students have not taken that course then a pair of simple doors will be made instead. The primary goal of this course will be to learn the steps of making a simple cabinet using hand and machine joinery. Quality of craft will be of great importance. Uniqueness of design will not be emphasized, however individuation of the cabinet will still be possible throughout the construction, starting with choices between a wall mounted or free standing (with legs) cabinet, the selection of hardwoods, the specific size of parts, and the selection of particular detail options. The construction process will be carefully staged with demonstrations continuing throughout the semester. The cabinet will be perpendicular and rectangular. Students will use standard mortise and tenons of various sizes, bridal joints, floating tenons, tongue and groove, spline and dovetail joints.

48-478 Digital Tooling

All Semesters: 6 units
This course serves as an immersive analysis of the available technologies located in the Digital Fabrication Lab at Carnegie Mellon and beyond. Students begin to understand equipment limits/boundaries, purposes and concepts; and the possibilities that arise from thoroughly comprehending how these tools work. During your Digital Experience, students begin to understand more systematically how to use these tools to their advantage. A better understanding of the equipment proves very useful towards a SoArch Student's 3rd, 4th and 5th years at Carnegie Mellon; but more importantly provides a fundamental understanding of a leading edge technology that will certainly prove itself as an integral tool for any Designer throughout their professional career. It is based on the idea that pushing the limits of design fabrication; comes from knowing the limits of your tools. The course operates by discovering tooling extremes; thus indicating limits, and then incorporating these boundaries (and/or breaking them) with Digital Fabrication methods and tooling; ultimately providing a platform in which students begin to understand and incorporate project efficiency. Prerequisites: Imagination, Laser Cutting, Milling and 3D-Modeling Experience required. (Rhinoceros 3D Preferred)
Prerequisite: 48-205

48-482 Advanced Structural Design: Computational Explorations

Fall: 9 units
This course covers advanced topics in computational structural design and analysis. Students will explore various form-finding algorithms and computational design methodologies, learning to use structural geometry as a key design driver for creating efficient and expressive forms. Key topics include: parametric structural modeling; computational structural analysis; structural optimization; and form finding. The course is hands-on and skill-focused, organized around interactive workshops and design projects throughout the semester, each addressing specific computational tools and design objectives. Students are expected to have basic knowledge of statics and structural design and be comfortable using Rhino and Grasshopper.

48-485 Design and Documentation in Revit

Fall and Spring: 3 units
This course will guide you through the process of designing in Revit from the schematic, conceptual design phase, to the construction document phase. The course will start with basic concepts moving on to more advanced topics. Layering information and how much to incorporate into the model, based on stakeholders and end users, will be discussed. Capturing the essential information from the BIM model will be explored to develop presentations, bidding documents, and construction documents to relay relevant information to clients, consultants, and contractors. We will discuss when it is imperative to model in 3D and when to overlay 2D linework detail. Real-time rendering techniques that streamline the design process will be explored using Enscape. The skills learned from this course will help you understand the phases of design and documentation in the Revit environment.

48-486 Systems, Cybernetics, Conversation

All Semesters: 9 units
Across many design disciplinesarchitecture and computational design, media and interaction design, design of services and organizationsmethods for grappling with complex adaptive systems is now table stakes. Furthermore, design today demands profound, authentic attention to equity, human and non-human living systems, climate and environment, sustainability and ethics. Overall, designers must have skills to collaborate in cross-disciplinary teams. An encompassing framework for these disparate disciplines and domains of 21st-century design is the transdisciplinarity (or "antidisciplinarity") of Cybernetics. Cybernetics can be understood as the study of "systems with purpose", whether machines or living things, including their unpredictable interactions. Central to Cybernetics is conversation as a mechanism of design, inclusivity, participation, innovation, and the impetus to action. The course offers systems frameworks and models of conversation that are also relevant to Designing for the Internet of Things (48-675), Inquiry into Computation Design (48-727), and Design Studies: Systems (51-277). Class time balances readings, discussion panels, and guest conversations with executing assignments that involve systems modeling; creating conditions for designing that are participatory and inclusive; and prototyping in a range of media (installations, screen-based interactivity, physical prototypes, workshops, etc.) that offer responses to global wicked challenges.

48-493 Representing Activism

Intermittent: 9 units
Efforts to promote social, political, economic and environmental change range in form from written word to direct action. Sources of injustice that those efforts address are multi-dimensional and complex. Effective forms of activism are fueled by creativity that synthesize and distill complex constellations of information and foster understanding. REPRESENTING ACTIVISM explores the role of multi-media graphic representation as a lens through which change and social justice can be fostered. Exploration of efficacy in application will span four dimensions, 1) Social Media, 2) Film, 3) Poster/Graphic Design, and 4) Publication - all aspiring to achieve the status of art. Art and Activism are predicated on exposing the truth. Art has the unique power to convey messages across linguistic and cultural barriers that often divide. Part of the Activist's challenge is to grip and inspire people to action. With the avalanche of information and media modern society absorbs every day, this is increasingly hard to do. Sometimes it is too much to ask people to stop and think: sometimes it's too much just to ask them to stop. Successful art compels this, penetrating apathy and imploring the viewer to look deeper and explore the narrative that is embedded in what elicited a visceral response. This seminar aspires to compel action in the public interest through artful representation.

48-494 Beyond Patronage

Intermittent: 9 units
TBD

48-497 Pre-Thesis

Spring: 3 units
This 3 unit course is designed for B.Arch and M.Arch students a year before their final Spring semester. The course develops an understanding of research methods, and explores the formation of ideas for architecture thesis projects. Many directions of architectural thinking (spatial, material, ideological and procedural), will be discussed and in framing a theoretical position we will see how an architecture thesis can use a creative process to discover and express findings in relation to large questions and to disciplinary discussions. This is a required course for Fall Thesis Seminar in F23 (9units) and Spring Thesis ASOS S24 (18units).

Course Website: http://soa.cmu.edu

48-500 Advanced Synthesis Options Studio

Fall
Having proven competency in the spectrum of skills determined necessary for tomorrow's architect during the first three years of the program, students in their fourth and fifth year are permitted to select from a variety of studio options, each providing the opportunity to build upon or augment some of those skills with new or more nuanced perspectives. All advanced synthesis studios are open to both years, the vertical integration offering enhanced learning opportunities.The content and focus of each studio is governed by faculty interests, which run the spectrum of architectural pursuits, ranging in scale from the design of a piece of furniture to a city and in approach from a comprehensive and complex building program to a critically-driven speculation. They may also be interdisciplinary in nature, taking advantage of the unique juxtapositions made possible at Carnegie Mellon.
Prerequisite: 48-410

48-505 Advanced Synthesis Options Studio III

Spring: 18 units
Having proven competency in the spectrum of skills determined necessary for tomorrow's architect during the first three years of the program, students in their fourth and fifth year are permitted to select from a variety of studio options, each providing the opportunity to build upon or augment some of those skills with new or more nuanced perspectives. All advanced synthesis studios are open to both years, the vertical integration offering enhanced learning opportunities.The content and focus of each studio is governed by faculty interests, which run the spectrum of architectural pursuits, ranging in scale from the design of a piece of furniture to a city and in approach from a comprehensive and complex building program to a critically-driven speculation. They may also be interdisciplinary in nature, taking advantage of the unique juxtapositions made possible at Carnegie Mellon.
Prerequisite: 48-105

48-510 Advanced Synthesis Options Studio IV

Spring: 18 units
The vertically-integrated advanced studios encourage interdisciplinary collaboration from arts, technology, research and design. They range from large scale urban and ecological projects, to detailed investigations of materials, and fabrication strategies.
Prerequisites: 48-400 Min. grade C or 48-410 Min. grade C

48-516 NOMAS Competition

All Semesters
Coming Soon.

48-517 Carnival Gateway Project Management

Spring
This course is for the team responsible or the design and project management of the Carnival Entryway Pavilion, to be completed for the 2023 CMU Carnival, April 13-15. The course is conducted by NOMAS and advised by Professor Vicky Achnani.

48-519 Architecture Design Studio: Thesis II/ Independent Project

Spring
Thesis is a year-long, independently defined research and design project that takes the place of upper level option studios. Thesis is an opportunity to develop skills, thoughts, and habits essential for future success, including mental discipline; independence of mind and judgment; working with advisors; the capacity to focus and pursue a subject in depth and over an extended time; the ability to design and execute a complex project; the skills of analysis, synthesis, and clear writing; and the self-confidence that grows from mastering a difficult challenge. Thesis topics and research agendas are generated by the student, but must be determined in collaboration with an advising team, and approved by a Thesis Coordinator. The School seeks to encourage an expansive range of rigorous and provocative inquiry as a culminating experience for the B.Arch education, including work that speculates, invents, or improves on existing ideas, practices, or systems through research and design; work that challenges the boundaries of the discipline and the profession, and moves beyond mere practice or solution-based work; worj that engages with open-ended and generalizable ideas, as much as with specific situations; work that projects or imagines a better future and an improved world; work that leads to the new knowledge, ideas, understanding, or paradigms. Acceptance into Thesis is dependent on passing the 48-497 ?Thesis Prep? course or its pre-approved equivalent, and submitting a rigorous thesis proposal to the Thesis Coordinator in late August, before the begin of classes.

Course Website: http://soa.cmu.edu

48-524 Building Performance Modeling

Fall: 9 units
"You can't hammer a nail over the Internet" Matthew B. Crawford, Shop Class as Soulcraft: An Inquiry Into the Value of Work The Design/ Build ASO Studio is part of a year-long, interdisciplinary, design-build project to provide a diverse group of students with the opportunity to work with their eyes, hands, and brains to transform an idea from a virtual world into the physical world. The elective is an opportunity for any student to join the spring "build" activity for 9 units. In this semester, we will again work campus constituents to improve the quality of life on campus through engaging design intervention(s). The project is fully funded, and the expectation is that the project will be turned over to the campus community by the last day of classes in the spring semester. During the fall, the Building Integration Option Studio (BIOS) students envisioned a farmer's market for Hazelwood Green creating design proposals at three scales-XL-M-XS. These design proposals for "XS" components will be a potential launching point for the spring build experience. These designs are just that-launching points-they have not been considered in the context of the Carnegie Mellon campus, so design will be a critical component of the early spring.
Prerequisite: 48-305 Min. grade C

Course Website: https://omerkaraguzelphd.wixsite.com/praxismodeling (https://omerkaraguzelphd.wixsite.com/praxismodeling/)

48-525 Thesis Seminar

All Semesters: 9 units
This seminar prepares undergraduate students planning to work on a thesis project in the following semester. Thesis work requires individual effort to identify a valid area of concern, understand the disciplinary discourse around a chosen topic and its cultural and social context, determine which are the appropriate means and methods to implement the project, and establish the criteria by which to evaluate the work. Students enter this course with an initial thesis statement, a body of background research and a set of questions that can be interrogated by engaging in research and discussion. The seminar help them refine the scope of the thesis argument, define appropriate research methods and sharpen communication about thesis work in all of its phases. In addition, it facilitates group conversation and exchange of ideas, providing dialogue, feedback, and continued motivation.

Course Website: https://soa.cmu.edu/courses (https://soa.cmu.edu/courses/)

48-527 5th-Year/Senior Seminar

Intermittent: 3 units
Seminar for students graduating from the Bachelor of Architecture and Bachelor of Arts in Architecture programs.

Course Website: http://soa.cmu.edu

48-528 IDeATe: Responsive Mobile Environments

Intermittent: 9 units
As part of this project-based course, we'll get hands-on with emerging technologies, concepts and applications in the Internet of Things through a critical lens. We'll prototype everyday intelligences and design smart and connected devices that examine and speculate on the strange, supernatural, and mystic qualities of the smart home. The first half of the semester will introduce students to building connected devices and intelligent spaces through technical development workshops, readings, applied explorations, and guest lectures. The second half of the semester will be organized as an applied collaborative project.

Course Website: http://daraghbyrne.me/teaching/responsive-mobile-environments/

48-530 Human-Machine Virtuosity

Spring: 12 units
Human dexterous skill embodies a wealth of physical understanding which complements computer-based design and machine fabrication. This project-oriented course explores the duality between hand and machine through the practical development of innovative design and fabrication systems. These systems fluidly combine the expressivity and intuition of physical tools with the scalability and precision of the digital realm. Students will develop novel hybrid design and production workflows combining analog and digital processes to support the design and fabrication of their chosen projects. Specific skills covered include 3D modeling (CAD), 3D scanning, algorithmic geometric modeling, digital and robotic fabrication (additive and subtractive manufacturing), motion capture and computer based sensing, and human-robot interaction design. Areas of interest include architecture, art, and product design.

48-531 Fabricating Customization: Prototype

Intermittent: 9 units
Architects have long flirted with production and manufacturing. This has been pursued to yield greater affordability, customization, and expression, and as of late, more carbon-aware material selection and manufacturing. This course builds upon this rich history and foregrounds architectural component customization to explore prototyping and customization within the context of contemporary practice. It introduces students to a range of prototyping and design for manufacturing frameworks. Through case studies and lectures, the course offers students an overview of existing and emerging modes of collaboration between designer and manufacturer in service to the production of a customized building component. The course places great emphasis upon the reciprocity of design and prototyping, challenging students to leverage physical artifacts as tools for thinking and testing. Throughout the semester, students will utilize additive and subtractive fabrication techniques to iterate the design of architectural components. Through this process, students will build proficiency in prototyping to design, test, and refine components of limited scope and scale.

Course Website: https://soa.cmu.edu/courses (https://soa.cmu.edu/courses/)

48-541 The Cut, The Beach and Beyond

All Semesters
The Cut, the Beach and amp; Beyond will be a FALL design elective with a SPRING build option studio working with Campus Design and amp; Facility Development, the Department of Civil and Environmental Engineering and campus constituents to improve the quality of life through design intervention(s) on campus.

48-543 Color Constructs

All Semesters: 9 units
In this course you will study and experiment with the relationships and perception of space and form through two- and three-dimensional optical experiments using color. Lectures, discussions, and field trips will delve into color theory particularly focused on the work of artist, designer, and educator Joseph Albers, look at culturally defined use of color, and its experience. In keeping with Albers definition of color theory as a hands-on experiential and experimental process of creating relationships through perception students will work on skills needed to craft compelling images using linear, planar and volumetric assemblies in digital and analog media. Initial weekly exercises will cover principles of color relativity, intensity, temperature, etc., and consider various principles of graphic perception including but not limited to vibrating and vanishing boundaries, figure ground reversals, and the illusion of transparency. Through this process you will gain an understanding of the use of color in the graphic representation of designs, patterns, diagrams and architectural representations that will inform the use of color in transforming the perception of space. The final assignment will be a three-dimensional color structure.

Course Website: http://soa.cmu.edu

48-545 Design Fabrication

Spring: 9 units
Design Fabrication is a project based seminar exploring the application of Computer Aided Manufacturing (CAM) in architecture. The course meets in the School of Architecture's Design Fabrication Lab (dFAB), which serves as a context to better understand the interconnected affordances of building materials, machine processes, and modeling software for design thinking. During the semester students receive hands-on introductions to dFAB equipment, including laser cutting, cnc routing, and 3D printing. Concepts will be explored and tested through iterative making/prototyping. Course Focus The course focuses on Transdimensional Fabrication, a manufacturing framework that forefronts design thinking across space and time. A growing array of approaches in contemporary architecture are motivated by this focus (e.g. flat pack, 4D printing, metamaterials, kinetic architecture, robotic origami, design for disassembly, etc.). We will investigate Transdimensional Fabrication concepts through three that forefront design translations: 2D 3D, Space Time, Assembly Reconfiguration Disassembly

Course Website: http://soa.cmu.edu

48-550 Issues of Practice

Fall: 9 units
Issues of Practice is a required course taught in the fifth year. It consists of three modules: Personal Promotion, Emerging Professional's Companion, and Excursions. The Personal Promotion module provides the students with a framework to create a resume, cover letter, and portfolio. The EPC (Emerging Professional's Companion) provides concentrated study in different aspects of professional practice. The Excursions require students to see how architecture relates to the wider world with architecturally related events that can include volunteer opportunities, lectures, mentorship, or teaching.
Prerequisite: 48-305

48-551 Ethics and Decision Making in Architecture

Spring: 9 units
Ethical Decision Making in Architecture is a required course in the fifth year of the Bachelor of Architecture Degree. It is part of a sequence dealing with professional aspects of the field of architecture, alongside courses like Human Factors, Real Estate Design and Development, and Issues of Practice. It builds on an understanding of the issues of occupancy, economics and practice in design decision making. The course covers basic frameworks of decision making and ethical adjudication through several case studies including Fallingwater, Sydney Opera House, Citicorp Tower, Pruitt-Igoe housing development, Crystal Palace and Kansas City Hyatt. The text for the course is a manuscript by the instructor entitled "Ethical Decision Making in Architecture".
Prerequisite: 48-205

48-554 Entangled: Remaking Nature from the Picturesque to the Hypernatural

All Semesters: 9 units
This seminar questions how we perceive, represent, and reconstruct our world in relation to evolving concepts of "nature" and their manifestation in architecture, art, and landscape. It is focused on the intellectual trajectories that define ecology and environment to arrive at the paradigm shift theoretician Donna Haraway has termed natureculture. We will first familiarize ourselves with historical ways of seeing "nature" and how this has formed the landscapes of the Anthropocene. This will help us put a critical lens on land, environmental and ecological art, ecoventions, architectural living systems, biomimicry, biophilia, and projective ecologies while we consider the influence of gardens, responsive landscapes, hyper-natures, and artificial ecologies in changing the way we design and build. We look for not only relevance but joy and beauty in practices that highlight the relation between desire, responsibility, more-than-human wellbeing, and ecological justice. This may help us build notions of care and stewardship and an understanding traditional and emergent cultural constructs that can define an eco-centric practice which shapes building futures. The course surveys texts from a range of topics including ecological aesthetics, architecture, art, landscape urbanism, and ecologically focused philosophy and theory. It includes weekly readings, discussions, presentations, and visual or written deliverables. Open to graduate and undergraduate students in Architecture and allied fields.

48-555 Introduction to Architectural Robotics

Fall: 9 units
This course provides an introduction to industrial robotics and automated fabrication within the field of Architecture. A series of lectures will cover the basic components, as well as their work flows, needed to design flexible automation - while work sessions will develop skills in hands-on programming, RAPID, work flow simulation, fixtures, and sensors. We will also issue competency-building projects within the lab environment in order to provide students with hands-on experience using the equipment. Upon covering the fundamental software and hardware content, an end-of-semester project will challenge you to apply your newfound knowledge to solve a final prompt. This is a portal course to all sanctioned coursework using the School of Architecture's Robotic Fabrication Lab. Upon successful completion, students will be eligible and prepared to enroll in advanced robotic fabrication courses.

48-557 Formless as an Operation

All Semesters: 9 units
This seminar focuses on the formless as an operation relative to social constructs, parametrics and aesthetics. Geometry is often thought of as a rational or a structure that secures and grounds things, however the structures of the built environment is an unfolding and indeterminate product. Social constructs can be defined as formless or the informe, as coined by George Bataille; an operational existence. In expanding the one's idea of operating, the use of formless allows us to consider the indeterminate. The indeterminate for our purpose in exploring context relative to spatial and cultural traditions. Within social and political space, traditions become spatial operators. How can we spatialize and draw traditions, rituals, and narratives? We will investigate the means and methods of representation relative to the formless and the built environment. Participants in the seminar develop an archive, original visualizations that utilizes multiple mediums and platforms, and culminate in a final project a part of an exhibition.

Course Website: http://soa.cmu.edu

48-558 Reality Computing

Fall: 12 units
Reality computing encompasses a constellation of technologies focused around capturing reality (laser scanning, photogrammetry), working with spatial data (CAD, physical modeling, simulation), and using data to interact with and influence the physical world (augmented reality / virtual reality, 3d printing, robotics). This semester the studio will focus on utilizing these technologies to capture places and objects to digitally recreate them for archives, artifacts, and interactive experiences. We will explore and analyze how to optimize these creations for real-time rendering and analyze how these platforms bridge the divide between "virtual" and "real."

48-560 Design & Redesign of Capital Cities

Fall: 9 units
This architectural and urban design history course examines the cultural histories of the design and redesign of world cities. The scale of urban interventions we will look at varies greatly, from the macro-scale of designing totally new capitals to the micro-scale of altering small nodes within a city. We explore the relationship between form and culture by considering political, social, economic, and aesthetic forces that have shaped the public realm of urban as well as suburban spaces. We focus on recognizing and understanding the rationale behind the design, re-design, and use of culturally important urban spaces during their own time, making periodic forays into the issues that influence those spaces today. Non-majors are welcome.

Course Website: https://soa.cmu.edu/courses (https://soa.cmu.edu/courses/)

48-564 Furniture Design & Construction

Spring: 9 units
This course is for students who already have a basic knowledge of hand tools and machines, and standard fabrication methods. Wood is the primary material, although other supplemental materials are permitted. One functional project will be built during the semester. Because all the equipment in the shop is traditional analog, the fabrication will remain analog. All operations will be done with hand tools or machines operated and controlled by hand. The emphasis of the design phases will also be non-digital. However recognizing the versatility of CAD, students will be permitted to advance and refine their ideas using their computer. One full scale orthographic drawing by hand will still be required, including plan, elevations, sections, and dimensions on 1/8" ply or mdf.
Prerequisites: 48-105 and (48-470 or 48-473)

48-568 Advanced CAD, BIM, and 3D Visualization

Fall
This course is designed to introduce a student to 3D software tools (3 units each), including Autodesk AutoCAD 3D, Revit Architecture, and/or 3D Studio MAX. Using building information and parametric modeling, materials, lighting, rendering, and animation students will create integrated CAD or BIM projects, 3D video animations, and realistic renderings. Students can choose to learn one, two, or all three applications. Course objectives are to develop an understanding of how to properly set up and manipulate 3D projects integrating software applications, replicating real world projects in leading architectural, lighting, design, construction, and engineering firms; learn how to create detailed 3D CAD models using surfaces and solids; learn about BIM parametric modeling using Revit Architecture; and learn how to apply materials, lighting, and rendering using AutoCAD, Revit, and 3D Studio Max. At the conclusion of this course, students will have 3D projects for one or more applications and animations if using 3DS Max. Students should have some familiarity with basic AutoCAD 2D commands. Those who don't have AutoCAD 2D knowledge can contact the professor to arrange for on-line tutorials that need to be completed before classes begin. The course will be primarily taught asynchronously via video lectures and other materials. Some live remote meetings will be held for topic previews and project reviews. In person and remote office hours will be held weekly.

Course Website: https://soa.cmu.edu/courses (https://soa.cmu.edu/courses/)

48-569 GIS/CAFM

Spring
A Geographic Information System (GIS) provides storage, retrieval, visualization, and analysis of geographically referenced data. GIS provides analytical tools to investigate spatial relationships, patterns, and processes of location-based data such as cultural, demographic, economic, environmental, health, physical, social, and other phenomena. GIS creates digital twins (virtual representations) of natural and built environments and integrates many types of digital models. GIS topics include geographic concepts (projections and map scales), map design, geodatabases (importing spatial and attribute data, geocodes, table joins, and data aggregation), spatial data processing, digitizing, data mining, multivariate cluster analysis, drive and walk time networking, raster GIS, spatial statistics (proximity and hot spot analysis), animation, and 3D GIS. CAFM (Computer Aided Facility Management) and IWMS (Integrated Work Management Systems) topics include space and asset management, building operations, environmental health and safety, and real property. The course includes in-person and asynchronous video lectures to learn important GIS concepts and a brief introduction to work management systems. Software tutorials cover leading GIS software from Esri Inc. Applications include ArcGIS Pro, ArcGIS Online, ArcGIS Map Viewer, ArcGIS Story Maps, and Dashboards. Subject areas are related to architecture, engineering, construction management, building performance, environmental health, sustainability, public policy, urban design, and planning.
Prerequisite: 48-205

Course Website: http://soa.cmu.edu

48-576 Mapping Urbanism

Intermittent: 9 units
This seminar provides the critical tools necessary to examine the city as both a representation and a reality in flux. Through an interdisciplinary framework, students study urban history, theory, visual thinking and spatial mapping. Contemporary urban issues are introduced through weekly lectures, readings, and class discussions. Parallel to these urban explorations, students learn to employ a diverse set of representational techniques to create inventive mappings. Upper-level (300 and 400 level) undergraduate students and graduate students are encouraged to register.

48-587 Architecture Lighting Design

Intermittent: 9 units
Through hands-on exploration of light students will develop a design process for lighting public spaces. All classes will be held in a fully equipped light lab to give the students full access to experimenting with light in design applications. Understanding how light creates focus and mood will be explored in class lab exercises. Discussion topics will include the role of the architectural lighting designer in the collaboration process, establishing design goals and a lighting point of view, communicating design ideas, analyzing successful lighting design in case studies for interior and exterior applications, and becoming familiar with the technical tools of lighting design. The final design project will include lighting mock-ups of a building site.
Prerequisite: 48-105

Course Website: http://soa.cmu.edu

48-596 LEED Buildings and Green Design

Spring: 6 units
Green building and sustainable design have been rapidly gaining acceptance in all sectors of the building market. Global issues of energy use, emissions, resource depletion, and land use are forcing building professionals to re-evaluate standard design and construction processes, and look to more environmentally friendly practices. The U.S.Green Building Council (USGBC) developed green building rating systems entitled Leadership in Energy and Environmental Design (LEEDTM) in order to define "green building" by establishing a common standard of measurement. LEED considers green building methods and technologies in several categories including site, water, energy, materials, and indoor air quality, and awards points towards an overall green building rating of certified, silver, gold or platinum. Currently, LEED registered projects make up 3% of the current U.S. commercial building market, and Pennsylvania is the third leading state with LEED registered projects. There is now a demand for design professionals with knowledge and experience not only in sustainable design but specifically with the LEED rating system as well. This course will provide students with background knowledge of the USGBC, the LEED system, as well as referenced standards related to specific topics. The course will benefit greatly from the large number of LEED projects in the Pittsburgh region, which will serve as case studies. Upon completion of the course, students will be prepared to take the LEED Professional Accreditation Exam, which is quickly becoming the standard of recognition for green building professionals.
Prerequisite: 48-315

48-607 Architectural Agency: Dig Where You Stand!

All Semesters
The course is organized as a graduate seminar that concludes the cycle of required courses in the history and theory of architecture for the MArch program. By revisiting histories of the twentieth and twenty-first centuries, it treats the profession as an uncertain, contested, and contingent category. It situates histories of architecture across continents in relation to developments, forces and processes including globalization, imperialism, nationalism, climate breakdown, (post)industrialization, as well as decolonization struggles and social, racial and gender movements. Instead of instrumentalizing architecture's history as a repository of formsa series of canonical buildings that each architect should recognize and reverethe course puts emphasis on relational thinking and contextualization. How did architects, buildings, and objects respond to the aforementioned developments and forces? How have architects addressed the ever-expanding crises of human displacement? How does the praxis of architecture contribute to the global environmental degradation? What type of reparative propositions have been put forth for a more equitable coexistence in a warmer, scarcer, and unstable planet? The course will take place in the archives of the Heinz Architectural Center at Carnegie Museum of Art. By digging in and out the Center's collection, the course focuses on specific case studies to bring to the foreground tensions, questions, relations, interdependencies, and alliances.

48-608 Co-designing an Indigenous Biodiversity Knowledge Learning Space for the Vertica

Fall and Spring: 12 units
The seminar emerges from the instructor's work while co-founding the "Vertical University" project in Nepal. As a subversion to the traditional way we understand knowledge, the "Vertical University" builds on the learning potential inherent in the place-based, deep-seated indigenous knowledge of farmers living in biodiversity-rich landscapes. The project spans across a vertical gradient starting at a 67-meter elevation in Koshi Tappu to Mount Kanchenjunga (the third tallest peak in the world) at 8,586 meters. For us, farmers are the professors; the villages are the classrooms, and the 8-000 meter vertical gradient is the "Vertical University." Across this belt, the project is anchored in six regions. However, the seminar will be focused on Kurule-Tenupa, a community where these imaginative ideas and aspirations come to life. A local community-based learning ground on 16 acres of land has been established under the leadership of local indigenous leaders. Through this elective and collectively with the community (online), we'll design this library as a new repository of knowledge that reinforces the local indigenous communities' relationship with their ecology. This production seminar aims to generate a design for the Indigenous Knowledge Library, which will be built in Kurule-Tenupa. If successful, this important typology, we hope, will be replicated in other parts of the project and, hopefully, throughout Nepal.

Course Website: https://soa.cmu.edu/courses (https://soa.cmu.edu/courses/)

48-610 Bizarre Details: stories of the ordinary, the uncanny, and the architectural com

Fall and Spring: 9 units
This design research course explores the current developments in hybrid, multi-platform design and communication mediums to prototype new ways of creative storytelling in architecture, visual development, and concept design. Research methods around oral storytelling, ethno-ecology, radical mapping, and the children's book can allow for the exploration of subjects in ways not available to typical architectural and urban research conventions. Throughout the Fall '23 Term designers will be tasked to use Pittsburgh, PA as a laboratory to develop a research project, from initial concept to an extensive script, including design elements, character development, as well as an urban critique of the city. Frameworks around composition, color, mapping, modeling, the parallel projection, and techniques in painting that are used in architecture, visual development, and concept design will ask how storylines translate and transform in the creation of a comprehensive project using industry techniques. To curate the explorations, we will explore innovative ideas in visual storytelling using techniques of interactivity in children's book design, experimenting with new forms of narrative strategies. The experimentations will result in a final exhibition at the end of Fall 2023.

48-611 On Speed / Space, Time & Information

All Semesters: 9 units
This seminar focuses on relations between architecture, information and computing technologies, and society as they are conditioned by speed: rates of transfer, response, exchange, movement, cognition, and more. Development in the last century has been marked nearly always by new velocities, at times testing or altering human tolerances for construction, for perception, for adaptation, for reliance on shelter and on computational systems. These roles of speed reveal ways that architecture and information systems embody shifts in culture, in technology, and in society - but also shifts in less obvious things like the emergence of global finance and geopolitics. Since late Capitalism and the rise of post/industrial economies, these shifts continue as indicators for unprecedented ecological and economic phenomena. Speed, in short, is not neutral or relative but always a function of its circumstance. In readings and class discussions, we will consider roles of speed in things like modular construction and shifts to rapid prototyping and fabrication; in the dissemination of Cybernetic thought; in evolving forms of public space with new telecommunications technologies; and in ecologies of material use. Readings in architecture, in media theory, in philosophy and more will explore ways that time is understood, is constructed in different ways, and to different ends. The seminar culminates with the recent movements toward "accelerationism" - rushing modernism and capitalism to some logical conclusions - and an interest in experiences beyond human perception in slowness.

Course Website: http://soa.cmu.edu

48-613 New Pedagogies

All Semesters: 9 units
Coming Soon.

48-614 New Pedagogies

All Semesters: 9 units
New Pedagogies are courses offered by new and visiting faculty (sections A-D). Please visit https://soa.cmu.edu/courses for complete course descriptions.

48-616 NOMAS Competition

Fall and Spring
Coming Soon.

48-617 Carnival Gateway Project Management

Spring
This course is for the team responsible or the design and project management of the Carnival Entryway Pavilion, to be completed for the 2024 CMU Carnival, April 11-14. The course is conducted by NOMAS and advised by Professor Omar Khan.

48-618 Discourse and Praxis in the Climate Emergency

Spring
This course engages with emergent modes of architectural thinking and praxis in the climate emergency. If buildings consume vast resources and are embedded in extractive systems of material and labor, how can discourse be deployed to consider other forms of praxis?

48-619 Machine Intelligence, Cybernetics and Design

Spring: 9 units
The course brings forward cybernetic epistemology, concepts, and models that bridge machine intelligence and the evolution of 21st-century architectural/design practice. The dominance of artificial intelligence, especially with the substitution of machine learning for the broader meanings of AI and more so for machine intelligence, has created a severely limited view of what computation can afford architecture/design, as well as the rapidly evolving techno-culture, and no less society and culture more broadly.

48-621 Beyond the Buildings Footprint

All Semesters: 9 units
This project-based seminar explores the use of machine learning and other software to create a speculative future for Braddock, Pennsylvania, a town just nine miles outside of Pittsburgh. To be mindful of the areas history and our engagement with it, we will study the work of LaToya Ruby Frazier to understand the social and ecological effects of steel extraction, emission, and construction. Frazier builds a visual archive of the intersection of the steel industry, the environment, and the human body, describing her work as excavations of hidden histories, from the micro to macro level. Students are encouraged to collect data using photography, film, record sounds, 3D scanning, and taking drone footage of the site. The workflow will deploy generative adversarial neural networks, various 3D modeling, and rendering software. Students will produce a short animation for the final deliverable. The seminar welcomes students with little or no experience with computation and those with more experience.

48-622 Explorations in Craft: Soft Forms, Stable Structures

Fall and Spring: 9 units
Softness is an evocative quality in architecture, but how do we "find" and then fabricate those elusive forms? How do we manipulate materials with control when the forms we seek, or their own structural makeup may lack it? When do we follow the material and when do we control it? This course is focused on physical model making of soft forms. It offers a series of encounters with material specificity, including textile, metal, and plastic materials, and the techniques used in transforming 2D patterns to 3D forms. Demonstrations, and workshops will inform material qualities, their formal affordances, and structural stability. Design and application of cutting and sewing patterns, bending jigs and casting molds will introduce the planning required to facilitate thoughtful crafting. The methods we work with are intended to open possibilities and refine skills for future making, ranging from quick form finding strategies to techniques for execution with precision. Note: A materials fee will cover workshop costs.

Course Website: https://soa.cmu.edu/courses (https://soa.cmu.edu/courses/)

48-623 Pittsburgh through the Archives

Fall: 9 units
This new class is designed for upper level Undergraduates and Master students who would like to delve deeper into the urban history of Pittsburgh and at the same time develop research skills that can be applied to other cities. In this small-group, hands-on elective seminar students engage with primary sources in the local archives, explore the urban environment with step-by-step guidance, gain insight from researchers with different disciplinary viewpoints and finally produce their own individual investigation as part of a collaborative class project.

48-625 Thesis Seminar

Fall
This seminar is designed for students planning to work on a thesis project in the M.Arch program and is intended to prepare students for a semester long, studio-based thesis project in the following Spring. You will enter this course with a written thesis statement, a body of background research related to your topic(s), and an initial set of questions that can be interrogated by engaging in research and discussion. Your continued progress is supported by the collective engagement of the seminar participants and the structure provided by course assignments and deadlines, in addition to individual conversations and targeted feedback from the instructor. The seminar focuses on refining the scope of the thesis argument, defining the methods to make the topic(s) of inquiry actionable through design-based methods, and sharpening the communication about thesis work in all of its phases. Thesis work is highly self-directed and requires a level of metacognitive thinking, which includes identifying a valid area of concern motivating the work, understanding the disciplinary and societal context for the project, identifying the means and methods for acting, and establishing the criteria by which to evaluate the work. The course is structured around the individual effort required to advance these aims. In addition, it facilitates group conversation and the regular exchange of ideas, providing dialogue, feedback, and continued motivation.

48-626 Bending Active System_ Bamboo Research Pavilion Using Robotic Arm and Steam Bend

Fall: 3 units
Bamboo, a material brimming with immense, yet largely unexplored, potential, particularly within the realm of architecture, stands as a testament to natures ingenuity. If we look at the current scenario, this fastest-growing, low-cost, carbon-sequestering natural resource remains an unconventional material, in the practice of Architecture, always given the peripheral roles of scaffoldings and at times more than that. This way the potential of such versatile material remains highly underutilized. Its time to shift our perspective and explore the full potential of this protean material in the 21st century. Grown tremendously in the developing parts of the global south, tooling bamboo has predominately relied on traditional techniques. Bamboo embodies flexibility, stiffness, and efficiency in material distribution, yielding lightweight yet efficient systems. This natures extreme product offers high resistance to tensile stresses, buckling, and bending stresses and its elastic properties are remarkable. The research taps into these properties of bamboo to arrive at a spanning and spatial system that stems from its intrinsic properties. Traditional ways of using bamboo as a whole culm restrict the abilities of spanning, and bending, and make it more vulnerable to splitting. Bending activates the tensile capacity of the bamboo and allows for more efficient material distribution. Combining bamboo and digital fabrication enables radically unique and spatially versatile configurations. Digital fabrication with this irregular material is challenging but immensely rewarding, unlocking new possibilities for shaping this material. CNC routing can offer efficient and precise sectioning of bamboo culm and bending bamboo using robotic arms reduces the burden of custom Jig for each new bend profile.

48-630 M.Arch Studio: Praxis 1

Fall: 18 units
TBA

Course Website: https://soa.cmu.edu/march (https://soa.cmu.edu/march/)

48-631 Fabricating Customization

Fall
to be created by the department
Prerequisite: 48-205

48-634 Architectural Theory & Contemporary Issues

Fall
This graduate seminar explores important writings and ideas being discussed in architecture today in relation to "Design Ethics," one of the central pedagogies of the SoA and the M.Arch program. Theory is framed not primarily as design principle, but as a critical framing device to investigate the dominant forces and paradigms engaging architecture today, in the academy, the profession, and the community. Architecture is considered as both material technology and social agenda, a driver of inequality but also potentially a social justice machine, a high-tech, economic, ecological, and political change-agent. The focus is on current discourses, processes, and contexts rather than on the history of theory, or the latest buildings or architects. The seminar examines a different theme each week, with topics that vary annually to acknowledge the dynamic nature of the profession, environment, and global contexts. The work of the seminar will focus on readings, weekly presentations and discussions about the sources. For additional units, students may elect to do a research paper on a theoretical aspect of architecture that connects to the co-requisite course "Situating Research" and might lead to a thesis or grant proposal.

Course Website: https://soa.cmu.edu/march (https://soa.cmu.edu/march/)

48-635 Environmental Systems: Climate & Energy in Buildings

Fall: 9 units
Our commitment to designing net zero energy and indeed carbon positive buildings and communities is critical to environment equity and the UN Sustainable Development Goals. This course introduces architectural design responses for energy conservation and natural conditioning, human comfort, and the site-specific dynamics of climate. The state of the art in building energy conservation and passive heating and cooling technologies will be presented in lectures and supported by readings and assignments. An overview of energy flows in buildings and energy design standards is illustrated by lectures on building energy conservation successes, and emerging demands for a broader definition of sustainability. To understand the significance of architectural design decision-making on energy consumption and comfort, students will compile a professional energy consultant's report for a residential-scale building, designing the most viable energy conservation retrofit measures for their client from siting, massing, organization, enclosure detailing, opening control, to passive system integration and management.

Course Website: https://soa.cmu.edu/march (https://soa.cmu.edu/march/)

48-636 Architecture & Agency

Spring: 9 units
Coming Soon

48-637 Structures/Statics

Spring: 9 units
We examine structural types, structural behavior, material behavior, and construction constraints that underlie our design of buildings, emphasizing the need for a designer to envision a complete 3-D structure. We mostly build "orthogonal structures" constructed in horizontal and vertical planes, requiring high-strength modern materials such as steel or reinforced concrete, comprising roughly 75-80% of the course. This is complemented by "geometric structure" where the three-dimensional shape dictates function; prominent examples include membranes, cable nets, historic masonry domes, and shells. Geometric structure is characterized by "form-finding." Statics underlies all topics, and our treatment is consistent with NCARB expectations.

Course Website: http://soa.cmu.edu

48-638 Structural Design 2: Materials and Analysis

Fall and Spring: 9 units
This course introduces fundamentals of strength of materials, computational modeling of structures and basic Finite Element (FE) analysis. This is a hands-on, skill-building course about learning how to translate a conceptual design intent into a computational structural model, then apply material and boundary condition constraints to analyze and understand structural behavior. These learning goals are achieved through three components: lab exercises, workshops and group design projects. Through a series of lab exercises, the students will learn the fundamental structural properties of standard construction materials (masonry, steel, concrete and timber), and learn how to perform basic calculations to understand the behavior of simple structures made of those materials under various loading conditions. Lab exercises are accompanied by hands-on workshops, where the students learn a specific computational tool or skill that will enable them to translate the lessons learned from the lab exercises into a computational design environment. The knowledge learned from the labs, together with the skills gained from the workshops, are then synthesized into group projects where the students will have an opportunity to apply and test what they have learned. Basic knowledge of statics and structural design is expected, and the students are assumed to have taken Structural Design 1 at CMU or an equivalent, introductory structural design course from another institute. Structural Design 2 is the second of three courses of the Structural Design curriculum offered at Carnegie Mellon Architecture.

48-640 M.Arch Studio: Praxis II

Spring: 18 units
Architecture transforms and shapes relations between individuals, communities, objects and environments. Praxis II will continue to understand architecture as a modulator of complex cultural and historical flows, but will aim to do so by intensively exploring, evaluating, and expanding the role that tectonic cultures and their associated modes of architectural expression play in shaping our world. Through a non-linear, multi-scalar, iterative design process, small teams will develop and refine detailed architectural assemblies attuned to methods of construction, craft, and labor practices; to the role of structural configurations in organizing the spatial distribution of occupancies and human experiences; to how envelopes regulate and respond to thermal and visual performance while also participating in aesthetic discourse; to ecological synergies and impacts; to modes of participation in carbon culture, including environmental management systems, commuting culture, and other patterns of integration with urban context; and ultimately to the disciplinary imperative to integrate/orchestrate these multiple systems. Students will develop design skills while negotiating the complex issues of site, program, climate, aesthetics, and performance. Students will use a range of technologies, such as daylighting and radiation simulation, and Virtual Reality, for designing spaces that respect the natural environment and engage human perception.

Course Website: http://soa.cmu.edu

48-641 History of Modern Architecture

Spring
This course investigates the global history of modern architecture and theory across the 20th century. We ask critical questions about the canon, the changing nature of history and theory, the biases embedded in terms like "modernism," "progress," and "Non-Western," and the deep legacies of colonialism, globalization, extractivism, and capitalism in which modern architecture so actively participated. The course loosely works backward in time to explore major movements and monuments of the Euro-American avant-garde and so-called "heroes" of modernism, but also diverse responses to modernity, including popular, tropical, vernacular, indigenous, and even anti-architecture around the world, including increasingly the Global South. The course content changes slightly every year to acknowledge the evolving understanding of the subject, but also to keep up with changes in architectural education, the discipline of architectural history, and professional practice, as well as changes in global culture, social context, and our student aspirations.

Course Website: http://soa.cmu.edu

48-642 History of Asian Architecture

Spring: 9 units
This course is intended to serve as an introduction to the evolution of urban spaces and the function of the architecture in South Asia, China, Korea and Japan. It is organized chronologically and will examine the impact of indigenous philosophical principles on the organization of villages, capital cities, and religious centers. The course will begin in the Indus Valley where complex urban planning along with public and private architecture flourished from 2600-1900 BCE. We will examine South Asian Hindu and Buddhist cave monasteries as well as freestanding Hindu temples and identify the salient architectural forms that identify each type. We will then move to China where the earliest villages were arranged according to ideas about nature and the organizing system of fengshui. By the earliest Chinese dynastic period, urban planning and building placement were beginning to be codified according to Confucian and Daoist ideals. Later Chinese imperial centers were consciously designed according to Confucian regularity and hierarchy in order to make visual statements about power. We will then move to consider urban organization and Buddhist temples in China, Korea to Japan where South Asian and Eurasian models were adopted and adapted. The examination of the Japanese warrior culture will include castles, new ideas in residential architecture, the Pleasure Quarters, and retirement villas. Contemporary architecture will be addressed through individual and group projects that will investigate specific structures and situate the buildings within the cultural and historic circumstances that led to their creation.

48-643 Color Constructs

Spring: 9 units
In this course you will study and experiment with the relationships and perception of space and form through two- and three-dimensional optical experiments using color. Lectures, discussions, and field trips will delve into color theory particularly focused on the work of artist, designer, and educator Joseph Albers, look at culturally defined use of color, and its experience. In keeping with Albers definition of color theory as a hands-on experiential and experimental process of creating relationships through perception students will work on skills needed to craft compelling images using linear, planar and volumetric assemblies in digital and analog media. Initial weekly exercises will cover principles of color relativity, intensity, temperature, etc., and consider various principles of graphic perception including but not limited to vibrating and vanishing boundaries, figure ground reversals, and the illusion of transparency. Through this process you will gain an understanding of the use of color in the graphic representation of designs, patterns, diagrams and architectural representations that will inform the use of color in transforming the perception of space. The final assignment will be a three-dimensional color structure.

48-644 M.Arch Pre-Thesis

Spring: 3 units
This 3 unit course is designed for B.Arch and M.Arch students a year before their final Spring semester. The course develops an understanding of research methods, and explores the formation of ideas for architecture thesis projects. Many directions of architectural thinking (spatial, material, ideological and procedural), will be discussed and in framing a theoretical position we will see how an architecture thesis can use a creative process to discover and express findings in relation to large questions and to disciplinary discussions. This is a required course for Fall Thesis Seminar in F23 (9units) and Spring Thesis ASOS S24 (18units).

Course Website: http://soa.cmu.edu

48-647 Materiality and Construction Systems

Spring: 9 units
This course introduces students to contemporary methods of construction and draws attention to the materialization of architectural intent. It foregrounds the historical, technological, and conceptual basis of construction systems to understand the building as a process and cultural artifact. The course provides an overview of established and emerging construction systems to reveal how and why building processes are utilized. Materials and methods of construction are positioned as both constraints and affordances, each with distinct spatial, structural, environmental, economic, and aesthetic concerns. Through lectures, readings, and detailed analysis, students will learn about the construction of fundamental architectural conditions, including foundations, walls, frames, envelopes, and roofs. Production methods, spanning the vernacular to the digital will introduce cultures of building and design for manufacturing considerations.

Course Website: http://soa.cmu.edu

48-649 Design Leadership

Spring: 6 units
This graduate seminar will explore architecture and adjacent creative fields for design leadership models to fuel future-forward speculation. How might we shape leadership and culture in a new design era?

Course Website: http://soa.cmu.edu

48-651 Vector Visions: Introduction to Image Processing and GenAI for Designer

Fall: 3 units
This mini-course integrates computer vision and generative AI for students in architecture, urban design, sustainable design, and related fields. It covers fundamental image processing and generative AI concepts like GANs and Diffusion models. Through hands-on projects, students will process and manipulate image data from buildings to urban landscapes. Students will build a solid understanding of image processing and discover its crucial role in emerging AI technologies. By the end of the course, students will be able to apply these skills to real-world design challenges, using tools such as Python, TensorFlow, and OpenCV.

48-652 Pixels to Photons: Introduction to Stable Diffusion and Projection Mapping

Fall: 3 units
This mini-course bridges parametric design, generative AI, and interactive visualization. Students will explore Grasshopper's parametric capabilities with Stable Diffusion, progressing from basic setups to advanced techniques. The focus then shifts to TouchDesigner, enabling the creation of dynamic projection mappings with Stable Diffusion outputs. Students will learn to build responsive environments, animate images, and develop real-time systems for design representation, gaining skills in computational design and AI-assisted creativity. By the end of the course, students will be able to create interactive projection mappings and animate images using Stable Diffusion, transforming digital parameters into captivating architectural visualizations and experiences.

48-658 Constructing Value(s): Economies of Design

Spring
This course explores the systems of economic, political, social, and regulatory forces driving the production of contemporary architectural projects. It critiques these systems, examines alternatives, and tests interventions in pursuit of value propositions outside of the bottom-line driven norms of late capitalism. What do design economies driven by equity, circularity, ecology, pluriversality look like? Through lecture and discussion, real world case studies in both for-profit and non-profit sectors, both locally and internationally, students explore the process of project development from multiple perspectives and gain insight into dynamics that determine if, how, and when projects are realized as well as relationships among various stakeholders, including architects, developers, and communities.

Course Website: http://soa.cmu.edu

48-667 Material Histories

Fall and Spring: 9 units
Materials affect the way we engage with a building and carry cultural meanings connected with complex histories, deeply and at times messily intertwined with the social, political and ecological context. In this seminar we will look at the history of the architecture of the last two centuries by following the thread of the history of materials. We will discuss the ways in which buildings of the past and the practice of architecture were affected by which materials were available, how they were produced, and the craft required to work them. We will reflect on how architects interpreted, manipulated, or added to those meanings through their own work. Materials' lifecycles and the networks of extraction, production, transportation, and reuse had an impact on the built environment in the past, just as they do today. We will learn from historical examples to assess the consequences of the choices we make as designers. Finally, we will critically engage with the presence of history as a layer of complexity embedded in the material itself - an effect that is compounded in the practice of reuse of materials with patina, marked from their past use.

48-668 Sankofa Bamboo Greenhouse

Fall
COMING SOON.

48-670 MArch Thesis

Spring: 18 units
Coming Soon.

48-674 History of Architecture in the Islamic World- A Primer

Fall and Spring: 9 units
An introduction to the architecture of the lands where Islam spread over the centuries, this course aims to provide a basic understanding of major epochs and regional variations. We will learn the function and meaning of the most important building types, examine how these types changed over time to adapt to the needs of changing societies and consider influences and exchanges with other traditions. We will examine the historical context within which art and architecture developed and explore critically the lingering signs of those traditions in contemporary society.

48-676 Connected Communities: Technology, Publics, Politics, and Participation

Intermittent: 6 units
This seminar examines how smart and connected technologies can be designed for neighborhoods, what considerations are involved, and what effects such technologies create for communities. We will introduce and critically examine the relationships between smart systems with the places, infrastructures, histories, politics, publics and problems that surround them. To do this, we will survey topics across research and practice across different domains. These will reveal approaches, methods and design factors to designing systems for communities, as well as the challenges created when computing becomes a non-human participant in communities and publics. The first five weeks of this mini-course will introduce a series of topical readings, cases, guest lectures, case studies, and design exercises. The rest of the course will invite students to investigate topics and contexts of interest to them. By the end of the course, students will be familiar with the socio-technical considerations for designing systems for places and publics.

48-677 Hines Competition

Intermittent: 3 units
This course is for graduate students participating in the prestigious national Urban Land Institute (ULI) Hines competition. This is an intensive real estate and urban design competition that will take place January 9 - January 23rd. Optional pre-competition preparation workshop sessions will be offered the week prior to January 9th. The course itself includes delivering and sharing competition entries and completing a post-competition survey. The purpose of the competition and companion course is for cross-disciplinary teams of graduate students to work collaboratively to create a complex urban design and real estate proposal on a real site in North America. Competition entries include a narrative, drawings and financial analysis. Each team will select and work with a design faculty advisor(s). This course is typically required for Masters of Urban Design (MUD) students. Previous real estate course work or knowledge is preferred. All registrants will be wait-listed until their teams have been registered with ULI (deadline December 9th). Please contact the coordinator Valentina Vavasis to participate.

Course Website: https://americas.uli.org/programs/awards-competitions/hines-student-design-competition/

48-682 Advanced Structural Design: Computational Explorations

Fall: 9 units
"This course introduces advanced topics in computational structural design and analysis. Through various form-finding algorithms and design methodologies, the students will learn how to use structural geometry as a key design driver to shape efficient and expressive forms. Typologies of structures that will be explored include but are not limited to: compression-only shell structures, tension-only membrane structures, compression-tension combined structures and fully spatial, non-manifold structures. Then, simple structural optimization techniques will be introduced and used to refine and improve the initially form-found geometries. Lastly, the class will also investigate various strategies for developing structurally-informed fabrication geometry. The course is organized around a series of hands-on workshops and several design projects throughout the semester, each addressing specific computational tools and design objectives. While the tools and methods that will be used in the course are digital, each project will emphasize physical fabrication and making, and therefore deliverables will always include both digital results and physical models. This is not an introductory course, and we will not be introducing basics of coding or structural analysis. Interested students are expected to have completed all required structural design courses in their respective curriculum at CMU or at previous institutions, and have a high-level understanding of all fundamental structural design concepts and ideas. The students will also be expected to have extensive experience in Python coding (comfortable writing their own geometric algorithms; we will not be using Grasshopper)."

48-685 Design and Documentation in Revit

Spring
This course will guide you through the process of designing in Revit from the schematic, conceptual design phase, to the construction document phase. The course will start with basic concepts moving on to more advanced topics. Layering information and how much to incorporate into the model, based on stakeholders and end users, will be discussed. Capturing the essential information from the BIM model will be explored to develop presentations, bidding documents, and construction documents to relay relevant information to clients, consultants, and contractors. We will discuss when it is imperative to model in 3D and when to overlay 2D linework detail. Real-time rendering techniques that streamline the design process will be explored using Enscape. The skills learned from this course will help you understand the phases of design and documentation in the Revit environment.

48-686 Systems, Cybernetics, Conversation

Spring: 12 units
Across many design disciplinesarchitecture and computational design, media and interaction design, design of services and organizationsmethods for grappling with complex adaptive systems is now table stakes. Furthermore, design today demands profound, authentic attention to equity, human and non-human living systems, climate and environment, sustainability and ethics. Overall, designers must have skills to collaborate in cross-disciplinary teams. An encompassing framework for these disparate disciplines and domains of 21st-century design is the transdisciplinarity (or "antidisciplinarity") of Cybernetics. Cybernetics can be understood as the study of "systems with purpose", whether machines or living things, including their unpredictable interactions. Central to Cybernetics is conversation as a mechanism of design, inclusivity, participation, innovation, and the impetus to action. The course offers systems frameworks and models of conversation that are also relevant to Designing for the Internet of Things (48-675), Inquiry into Computation Design (48-727), and Design Studies: Systems (51-277). Class time balances readings, discussion panels, and guest conversations with executing assignments that involve systems modeling; creating conditions for designing that are participatory and inclusive; and prototyping in a range of media (installations, screen-based interactivity, physical prototypes, workshops, etc.) that offer responses to global wicked challenges.

48-692 Shaping Daylight Through Simulation and Virtual Reality

Fall: 9 units
Light is one of the critical aspects of valued architectural spaces, influencing ambiance, the overall atmosphere, and occupant perception, whether positively or negatively. In this course, we will explore the quantities and qualities of light. We will study how we can design with and for light while understanding the paradox of lighting designthat it is both science and art. Digital design and simulation tools will be augmented with virtual reality (VR) to extend quantitative measurements of lighting to include qualitative aspects of light such as its influence on occupants' subjective impressions of a space, wellbeing and comfort.

Course Website: http://soa.cmu.edu

48-699 Environmental Racism, Injustice, & Unfreedom: Lessons for Architecture

All Semesters
Environmental racism refers to the disproportionate concentration of environmental harms in low-income communities of color (particularly Black and indigenous communities) through the systematic workings both historic and ongoing of white privilege and white supremacy. More broadly, environmental injustices also include restrictions to environmental resources and infrastructures, and the unjust placements and displacements of communities of color resulting from uneven development. In this seminar we will examine the histories of environmental racism and injustice through close reading of literature from a range of fields including Environmental Justice, urban political ecology, Black geographies, and indigenous studies. We will ground our conceptual understandings through a closer look at ongoing environmental justice issues in Braddock and North Braddock, including through dialogue with local advocates and community members. Through the course of the semester students will develop a case study focusing on air pollution in the Mon Valley region, working collaboratively to produce an annotated bibliography of atmospheric pollution and community action.

Course Website: https://soa.cmu.edu/courses#graduate (https://soa.cmu.edu/courses/#graduate)

48-701 Entangled: Remaking Nature from the Picturesque to the Hypernatural

All Semesters: 9 units
This seminar questions how we perceive, represent, and reconstruct our world in relation to evolving concepts of "nature" and their manifestation in architecture, art, and landscape. It is focused on the intellectual trajectories that define ecology and environment to arrive at the paradigm shift theoretician Donna Haraway has termed natureculture. We will first familiarize ourselves with historical ways of seeing "nature" and how this has formed the landscapes of the Anthropocene. This will help us put a critical lens on land, environmental and ecological art, ecoventions, architectural living systems, biomimicry, biophilia, and projective ecologies while we consider the influence of gardens, responsive landscapes, hyper-natures, and artificial ecologies in changing the way we design and build. We look for not only relevance but joy and beauty in practices that highlight the relation between desire, responsibility, more-than-human wellbeing, and ecological justice. This may help us build notions of care and stewardship and an understanding traditional and emergent cultural constructs that can define an eco-centric practice which shapes building futures. The course surveys texts from a range of topics including ecological aesthetics, architecture, art, landscape urbanism, and ecologically focused philosophy and theory. It includes weekly readings, discussions, presentations, and visual or written deliverables. Open to graduate and undergraduate students in Architecture and allied fields.

48-706 Urban Design Studio II: Urban Systems

All Semesters: 18 units
Optimistic assessments about Pittsburgh's livability mask a complicated reality where prospects for health and well-being are starkly differentiated along lines of race, class, and gender. Environmental harms, underpinned by the ongoing legacies of industrial production, extraction, and segregative planning, create a toxic combination adversely impacting human health, ecology, and community futures. These challenges necessitate multidisciplinary, collaborative, and emancipatory approaches to knowing the built environment, and community-centered methods in urban design that attend to the local histories, embodied knowledges, and political ecologies of life in toxic systems. This studio will expand on MUD students' understanding of neighborhood-scaled urban design through the examination of urban systems and systemic processes, focusing on the infrastructures of toxicity, and modes of local action against them. It will be anchored in an ongoing collaboration with North Braddock Residents For Our Future, a grassroots organization which has led the opposition to unconventional gas drilling and environmental injustice in Braddock and North Braddock and surrounding communities.

Course Website: http://soa.cmu.edu

48-709 History and Future of Interaction Design

All Semesters: 12 units
The history of Interaction Design (IxD) is far richer than what is visible from today's tech. Many great ideas have been mangled and even lost. By making prototypes inspired by this history, we reach new insights and illuminate a future of promises and perils. In this course you begin by mining historical IxD innovations by building prototypes in a modern vernacular that forefront lost contributions. In 3 sprints you render a powerful but lost essence in the form of a concept storyboard, video, or clickable prototype. Thus you explore the History of IxD. To explore the Future of IxD, you are invited to invent itby developing your own vision in the design of a final project prototype with the focus and scope that you control. Coursework is partly historical review and largely designing and producing prototypes in a studio setting, especially suited for backgrounds in interaction design, computational design, responsive architecture, media, or coding.

48-711 Paradigms of Research in Architecture

Spring
Architectural "research" by many practitioners is often limited to precedent studies and/or intuitively evaluating alternative design solutions and materials. Deeper analytical activities risk being perceived as unnecessary overhead expenditures. On the other hand, "architectural" research by many scholars is often confined to laboratory settings or so esoteric that the findings are of little use to practitioners. This course challenges the false dichotomy between these two frames and provides an introduction to a wide range of research strategies including Experimental, Simulation, Quantitative, Qualitative, Correlational, Interpretive-historical, Logical Argumentation, Case Study, and Mixed Methods. Throughout the semester there will be guest lectures from faculty who will share their expertise, successful research strategies and methods, innovative ideas for future research, and the results of their current and past research. Students will apply a variety of research paradigms and methods to their research interests, improve their verbal and visual presentation skills, and prepare a research proposal presentation with a problem statement, literature review, methodology/methods, anticipated findings, and bibliography.

Course Website: http://soa.cmu.edu

48-712 Graduate Seminar 2: Issue of Global Urbanization

Intermittent
Abstract: By 2050 the number of urban dweller across the world will double. The seminar is an investigation into the future of cities focusing on three existential challenges: the escalating environmental crisis, growing social inequity and technological dislocation. In the face of these wicked problems, we will address the role and agency of designers and planners, decision makers and citizens in tackling what Jeremy Rifkin describes as the Third Industrial Revolution and how to lay the foundational infrastructure for an emerging collaborative age. These issues are explored through contemporary writings and case studies that situate urban transformations in the US within a broader global context, with a specific focus on the political as articulated through the negotiation of top-down planning and bottom-up behavior of cities. The seminar course will revolves around reading reflections, in-class presentations and student moderated discussions on theories and case studies of global urbanization. This is a 3- or 6-unit course that requires attendance at one 1.5-hours class per week. The extra credits involve a more extensive final paper. Students from diverse disciplines are welcome in this seminar. Key Topics: Global Urbanization, Uneven Growth, Political Economy, Ecological Urbanism, Resilience, Cosmopolitan Localism, Smart Cities, Commons. Course Relevance: An understanding of theories and practice of urbanism in global developments. Course Goals: The seminar provides an understanding of the social, political, economic and environmental forces at play in shaping our built environment and reflects on the role and agency of designers and planners can have in building more resilient and sustainable cities.

Course Website: http://soa-cmu.edu

48-713 MUD Urban Ecology

Fall: 9 units
Urban ecology describes the complex relationships between humans and our environment and is bound by an understanding of system dynamics. Urban ecology draws from our understanding of urban settlements and the cultural values that shape them, as well as our conception of ecology as the resources and flows that support biotic systems. Urban ecology situates humans and our activities as part of a dynamic and living environment that is more continuum than a dichotomy. This class will examine the shifting regimes of urban ecology and equip students with skills and core concepts that enable them to lead or contribute to transition through design. As designers we are trained to see patterns and #8212;urban ecology asks us also to see processes and to speculate on effects and possible outcomes. This course will discuss the systems and the logics that create the patterns, and we will explore how our design process may be different when dealing with the ambiguity and uncertainty of systems design. We will learn the fundamentals of systems dynamics modeling as it applies to the design of historical and contemporary landscapes, infrastructure, and spatial practices at the macro-, meso-, and micro-scales.

Course Website: http://soa.cmu.edu

48-715 MSCD Pre-Thesis 1

All Semesters: 6 units
This seminar introduces graduate students in Computational Design to the rudiments of graduate level academic research, and offers a space to discuss inchoate research methods, questions, and projects in the field. Assignments require students to gain familiarity with past and current research in the field in order to distinguish different research traditions, practices, opportunitiesand pitfalls. An emphasis is placed on the materialities and socio-technical infrastructures of computing.

Course Website: http://SOA.cmu.edu

48-716 MSCD Pre-thesis II

All Semesters: 6 units
With the notion of "critical technical practice" as a touchstone, this graduate-level seminar draws from across design, media, and science and technology studies to cultivate an awareness of the discursive and political dimensions of technology in design, and to guide participants in the formulation of a graduate thesis in computational design. Through readings, discussions, written assignments, and presentations participants develop the skills to identify and refine a research question, situate it within a wider scholarly conversation paying attention to ethical citational practices argue for its relevance, and creatively engage with conceptual and methodological research challenges. As a final deliverable, participants produce a thesis proposal and present it to faculty and students.

Course Website: https://soa.cmu.edu/courses#graduate (https://soa.cmu.edu/courses/#graduate)

48-720 Planning by Design: Campuses, Waterfronts, Districts, and Cities

Spring
In responding unprecedented challenges of density, information, equity, and climate change, cities continue to define and design "districts." Waterfront, historic, arts, innovation and ecodistricts draw on models including on university/corporate campuses, neighborhoods, main streets, and downtowns. How can cities remake districts in that are viable in terms of engagement and opportunity? How can they be meaningful and inclusive in a society that appears to be increasingly less place-based? Through presentations, case studies, and the semester project, students will develop strategies to respond to these challenges.

Course Website: http://soa.cmu.edu

48-721 Building Controls and Diagnostics

Intermittent: 12 units
The course will introduce students to collecting and processing data acquired from building systems and evaluating their performance. It will discuss the basics about control systems, including both traditional control logics, like rule-based control and model predictive control, and advanced control logics like reinforcement learning based control. Proficiency in Python and maturity in mathematics is required. Knowledge of website design and reinforcement learning is recommended.

Course Website: http://soa.cmu.edu

48-722 Building Performance Modeling

Fall
This graduate-level course examines the emergence of computation as a pivotal concept in contemporary architecture and design through a selection of design theories and practices responding to the so-called "computer revolution". An aim of the course is to explore computation beyond particular technologies and tools, and to cultivate an awareness of design technologies as cultural artifacts shaping disciplinary identities and worldviews, and shifting conceptions of design, creativity, nature, body, and place. The semester is divided into two-week thematic modules, often with computational design faculty participating as guests covering topics derived from their own research. Each module includes readings and a short team-based project expanding on the topic introduced. Topics include among others shape grammars, tangible interaction, responsive environments, cybernetics, and architectural robotics. The course also introduces participants to the rudiments of academic research, in particular to the elements and structure of an effective research paper. Participants practice reading and responding to both historical documents and contemporary research related to each topic, and develop a critical understanding of a rapidly expanding landscape of hybrid practices, theories, and research methods linked to computational and interactive forms of creative practice.

Course Website: https://soa.cmu.edu/courses#graduate (https://soa.cmu.edu/courses/#graduate)

48-723 Performance of Advanced Building Systems

Spring
Advanced Building Systems Integration This is a graduate level course that focuses on commercial building performance achieved through systems integration. In lectures, class discussion, and student projects, we will explore the topic of building performance, the design and technical strategies that support sustainable high performance; the design, construction and operation processes that are likely to produce sustainable high(er) performance buildings; and the current state of theory versus practice. The course assumes a basic understanding of buildings' impact on the environment, of building design and materials performance, and the calculation of building heating and cooling loads. On that foundation, we will examine the concept of systems integration and how this approach can sustain the occupants and the environment far better than conventional design, construction and operation. Although US climate, building conventions and codes will be our reference point, we will broaden our discussion by using examples and data from many other countries. An essential aspect of our exploration will be identifying successful built projects and examining the factors that may have allowed those projects to succeed. If this course meets its objectives, students who successfully complete the material will understand and be able to discuss sustainable building performance characteristics, will understand the systems integration approach and how it differs from conventional approaches to building design, and will know how to positively affect architectural and engineering decisions to support the design, construction and operation of sustainable high performance buildings.

48-724 Scripting and Parametric Design

Intermittent: 10 units
This course prepares students for modeling geometry through scripted development of parametric schemes primarily for design applications that is, to introduce students to basic scripting in geometrical modeling environment with a focus on algorithms relating to form making and to reinforce and extend basic concepts of parametric modeling. Contemporary approaches to modeling geometry are computational reflected in designers wanting much more control over the generative process by varying parameters, in turn, enhancing the efficiency with which they navigate design variations, analyze design artifacts and explore design manifestations. This course has two parts: firstly, to supply the basics of object-oriented programming and algorithmic thinking using Python language constructs, and secondly, to supply the basics of scripting generative form making specifically, by customizing procedures for generative design via scripts in GhPython in conjunction with Rhino/ Grasshopper objects. A number of different form-making algorithms are explored, e.g., fractals, rule-based models, cellular models, agent- based models, and optimization- based models. The course consists of lectures, computer instruction and weekly assignments. Prior exposure to Rhino/ Grasshopper is required.

48-725 Graduate Real Estate Development

Fall
This course teaches the fundamentals of real estate development in the U.S. You will learn about the real estate development process and the social, economic and regulatory context in which land use and real estate development take place. We will learn about project team members and processes; market research; site constraints and zoning; basic project budgeting and types of funding sources. We will also discuss social equity issues related to land use, including affordable housing, racial segregation and economic inequality. This course typically includes international students which allows us to learn from each other and compare real estate and land use issues in various countries. The primary objective of this course is for students to understand how these issues might affect their professional and personal lives, whether they become designers, contractors, engineers, public policy professionals or real estate developers. The course includes learning terminology, reading current news articles, and completing a team project, sometimes with a Pittsburgh-based client. Students will have the first two weeks of class to select nine or 12 credits; 12 credit students will complete additional work. Open to graduate students from any school including SoA, Tepper and Heinz Undergraduates with instructor permission only

Course Website: https://soa.cmu.edu/courses#graduate (https://soa.cmu.edu/courses/#graduate)

48-729 Sustainability, Health and Productivity to Accelerate a Quality Built Environmen

Fall
Given the United Nations Sustainable Development Goals and the growing demand for sustainable design, professional practices are "tooling up" around the world to deliver high performance and environmentally responsible buildings, infrastructures and communities. However, investments in 'green', high performance building solutions and technologies are still limited by first cost decision-making, and life cycle tools are still largely inaccessible to professionals. This course explores the relationship of quality buildings, building systems, infrastructures and land-use to productivity, health, well-being and a sustainable environment. The course begins with a series of lectures on high performance enclosure, mechanical, lighting, interior and networked building design decisions and extends to sustainable communities and infrastructures. The course engages students in the research literature that relates these building design decisions to multiple cost/performance impacts, including: energy, carbon, facilities management, organizational change, technological change, attraction/retention (quality of life), individual productivity, organizational productivity, salvage and waste (the circular economy), tax and insurance, and critically to environmental and human health.

Course Website: https://soa.cmu.edu/courses#graduate (https://soa.cmu.edu/courses/#graduate)

48-731 Sustainable Design Synthesis Prep

Spring
Synthesis Prep is an intensive course designed to help students refine their research plan and prepare for their synthesis project. Over the course of the semester, students will develop a research plan, present their research goals and findings, and author a preliminary report. With a refined timeline and deliverables, students will evaluate the efficacy of their approach and update their plan as necessary. The course will provide students with a comprehensive understanding of their area of study, with critical excerpts organized and professionally cited. Through field work, simulation, and analysis, students will initiate new contributions to ensure that the Synthesis methods, timeline, and deliverables are feasible within the Spring semester.

Course Website: https://soa.cmu.edu/courses#graduate (https://soa.cmu.edu/courses/#graduate)

48-733 Environmental Performance Simulation

Intermittent
"Design of a boat is optimized for sail-driven locomotion. Buildings should be able to sail using free energy if wind, air, sun and internal heat sources to temper indoor environment", Brendon Lewitt. Based on this viewpoint, this course introduces fundamental knowledge in building physics in relation to a range of environmentally responsive building design principles and computational approaches for increased resiliency for human habitability with minimal reliance on mechanical systems. EPS course refreshes some of the fundamental building physics topics such as building thermodynamics (heat and amp; mass transfer mechanisms), photometric quantification of light and luminous environment, human visual and thermal comfort, thermal modeling and the principles of generating electricity from sunlight (photoelectric effect). EPS course outlines a series of environmental design principles with emphasis on evidence-based design approaches and reviews of building case studies are evaluated against actual buildings in operation. Focus is also given to integration of multi-valent environmental design strategies into the early stages of performative architectures. EPS also introduces state-of-the-art architectural design and amp; research oriented environmental performance simulation and amp; visualization tools, methods and techniques (based on the algorithmic/parametric modeling ecosystem of RHINO-Grasshopper-DIVA-ArchSIM -Ladybug-Honeybee programs). Computational introductions will be accompanied with pre-established/seed workflows which are ready for future adaptation and extension by the students.

48-737 Detailing Architecture

All Semesters: 9 units
"This course examines the role of the architectural detail in the formation/ thematic development of a work of architecture and how the detail reinforces the theoretical position of the architect.

Course Website: http://soa.cmu.edu

48-738 Special Topics: Ecological Footprints

Fall: 6 units
The Ecological Footprint is a measure of the demand that human activity puts on the biosphere. More precisely, it measures the amount of biologically productive land and water area required to produce all the resources an individual, population, or activity consumes, and to absorb the waste they generate, given prevailing technology and resource management practices (Global Footprint Network 2010). This course will engage students in the metrics and impacts of our collective consumption and waste of: -Energy -Materials (Cradle to Cradle) -Food -Water -Transportation -The Integration of Systems towards Quality of Life Starting at the global context, this course will address challenges/opportunities to advance regenerative practices, improving our relationship to nature. Learning from international best practices, we will continue to explore ecological footprints at the global, national, regional, city, neighborhood, building and individual scale. The course will be based on lectures and readings, with assignments and student presentations to fully explore each of the footprint characteristics. Experts on water, energy, materials, food and other resources have been invited to lecture. By mid semester, an application project will be selected for ecological footprint analysis and the development of design, engineering, and operational guidelines towards reducing that footprint. The potential application projects include: the CMU campus footprint and Donner House retrofit; the Energy Innovation Center and education of the trades in reducing our regions footprint; or a new Net Zero building for Carnegie Mellon University. This will be a collaborative effort.
Prerequisite: 48-305

48-739 Making Things Interactive (Graduate)

Fall: 12 units
In this hands-on design-build class you will learn the skills to embed sensors and actuators (light, sound, touch, motion, etc.) into everyday things (and places etc.) and to program their interactive behavior using a microcontroller. You'll also dive into the fields of VR/AR/MR and experiment with combining these disciplines with physical computing. Through weekly exercises and a term project the class will introduce basic analog electronics, microcontroller programming, projection mapping and virtual reality; as well as exploration into using kinetics and materials to make the things you design perform. Emphasis will be on creating innovative experiences. The graduate edition of this course will require additional work including a paper that can be submitted to a peer-reviewed interaction design conference such as CHI, UIST, or TEI. Students from all disciplines are welcome: but please note that the class demands that you master technical material. Experience in at least one of: programming, electronics, or physical fabrication is strongly recommended.(Participants will provide their own supplies and materials.)

48-743 Introduction to Ecological Design Thinking

Intermittent: 9 units
This seminar offers an overview of scholarly, design-based and research-based approaches to issues of ecology and sustainability in architecture and urban design. The seminar intends to question contemporary paradigms of sustainability within the built environment and includes inquiries from different disciplinary perspectives ranging from history, theory, technology, engineering, art and design. The goal of this seminar is to offer a platform for critical thinking, in-depth discussion and analysis of actionable methodologies related to sustainability, and procedures relevant to the shaping of our physical environment and social systems. Composed of a series of lectures, readings and short assignments, this seminar will lead students through a diverse collection of interdisciplinary views and positions towards defining what is our understating of sustainability today, and what is a role of large scale ecology within the constructed environments. Students will be introduced to a wide overview of technical, analytical, practical, theoretical and intellectual inquiries that will help them to navigate varied fields of expertise and enable their future investigation of innovative sustainable strategies for the built environment. This seminar will consist of majority of lecture sessions and 2 project review sessions, spread across the fall semester. Each session will introduce set of readings and/or a small exercises related to the lecture theme. The invited lecturers come from both: academia and practice. Invited speakers' areas of research and design work feature diverse approaches to issues of sustainability and technology. This seminar serves as a platform for development of a cross-disciplinary theoretical foundation to investigate varied methodologies towards sustainable design practice.

48-745 Design Fabrication

Fall and Spring: 9 units
Design Fabrication is a project based seminar exploring the application of Computer Aided Manufacturing (CAM) in architecture. The course meets in the School of Architecture's Design Fabrication Lab (dFAB), which serves as a context to better understand the interconnected affordances of building materials, machine processes, and modeling software for design thinking. During the semester students receive hands-on introductions to dFAB equipment, including laser cutting, cnc routing, and 3D printing. Concepts will be explored and tested through iterative making/prototyping. Course Focus The course focuses on Transdimensional Fabrication, a manufacturing framework that forefronts design thinking across space and time. A growing array of approaches in contemporary architecture are motivated by this focus (e.g. flat pack, 4D printing, metamaterials, kinetic architecture, robotic origami, design for disassembly, etc.). We will investigate Transdimensional Fabrication concepts through three that forefront design translations: 2D 3D, Space Time, Assembly Reconfiguration Disassembly

Course Website: http://soa.cmu.edu

48-746 Shape Machine

Fall: 9 units
A shape machine is any computational technology that fundamentally expresses the way shapes are represented, indexed, queried and manipulated. In this course the shape machine is based on visual rules (shape rules) grounded in symbolic rules (programming language instructions) to provide a robust technology to individuals who use drawings and visual models to develop and communicate their ideas. A shape machine is intended to be a computational, visual and disruptive technology for shape cognition and computing, which intersects with such fields as design, artificial intelligence, computer science, and mathematics. We consider a particular kind of shape machine - spatial grammars - which have their origin in formal grammars for spatial composition. Grammatical approaches to designing offer an alternative to traditional approaches. The goal of grammars is not to produce a single design as the final outcome, but, rather, to provide an understanding of the underlying spatial relations that come into play in an eventual design. For nearly three decades, grammars have been studied extensively to understand style in architecture, engineering, design, fine art and ornament. Recently, there has been an increasing application of grammatical ideas to other disciplines. Specifically, there is resurgent interest in implementing shape grammars for application. This is the focus of this course.
Prerequisite: 48-724

48-749 Special Topics in Computational Design

Intermittent: 6 units
Today's wicked challenges are many-dimensional and fundamentally intractable, yet countless members of our university have great passion to confront them. Systems thinking and rigorous approaches to complex adaptive systems are required to model the nested entanglements across social, technical, and environmental contexts. However, the required systemic models and their underlying principles are not available in approachable form and have generally not been expressed in terms of wicked challenges. To address this gap, students in this seminar take part in researching and designing a global public colloquium called Colloquies for Transgenerational Collaboration to be held in hybrid mode in Fall 2023 at CMU. The unique organizing principle is to proceed from the concerns, worldview, and values of grad students and rising faculty, who will then be paired with local and international practitioners in systems, cybernetics, and wicked design challenges. The resultant public conversations will become the basis for on-going design and co-creation, to be documented and widely shared to benefit future researchers.

48-750 Design & Redesign of Capital Cities

Fall: 9 units
This architectural and urban design history course examines the cultural histories of the design and redesign of world cities. The scale of urban interventions we will look at varies greatly, from the macro-scale of designing totally new capitals to the micro-scale of altering small nodes within a city. We explore the relationship between form and culture by considering political, social, economic, and aesthetic forces that have shaped the public realm of urban as well as suburban spaces. We focus on recognizing and understanding the rationale behind the design, re-design, and use of culturally important urban spaces during their own time, making periodic forays into the issues that influence those spaces today. Non-majors are welcome.

Course Website: https://soa.cmu.edu/courses (https://soa.cmu.edu/courses/)

48-752 Zero Energy Housing

Fall: 9 units
Are you interested in designing or renovating the high-performance multifamily housing of the future? Would it surprise you to know that despite numerous successful single-family projects, only a limited number of successful multistory, multifamily zero examples exist? Creating multifamily housing that reaches net zero or carbon neutral goals is challenging since occupant behavior can influence the outcome as much as building design and construction. Yet multifamily housing is an essential typology to address rapid development and urbanization. Take on the challenge of creating high performance housing for our net zero future by exploring the technical and social demands of multifamily zero energy design or renovation. 48-752 is a graduate level course designed to support that goal. Through lectures, outside research, discussion, and a final applied project, you'll explore the design approaches, codes, policy, technology, and energy infrastructure options that can help you achieve the housing performance we know is essential for a sustainable future.

Course Website: http://soa.cmu.edu

48-753 Intro to Urban Design Media

Fall: 6 units
This course explores new forms of media and representation in Urban Design. The seminar is a project-based course consisting of bi-weekly exercises and reading assignments. Students will adopt their own hometown as the primary site for their analysis and representation. Throughout the semester, students are tasked with identifying a specific subject unique to their site of inquiry. They will then analyze, interpret, and re-represent their subject through a variety of media, including collages, maps, images, renders, matrices, animated GIFs, and AI-generated imagery. Consideration will be given to drawing/image quality, technique, and aesthetics.

48-755 Introduction to Architectural Robotics

Fall: 9 units
This course provides a practical, hands-on introduction to the application of industrial robotics in architectural and related construction domains. It also provides students with the necessary knowledge and safety protocols to work in the architectural robotics lab at CMU SoA. Through lectures, labs, and project work you will learn the industrial robotic fundamentals of on-line programming, off-line programming, simulation, end-of-arm-tool (EOT) development, workcell development, and interacting with peripheral sensors. This course is a prerequisite for more advanced engagement with the lab equipment through SoA courses, student thesis projects, and research. No prior knowledge of industrial robotics is required to succeed in the course. Students should have basic knowledge of Rhinoceros 3D modeling and visual scripting in Grasshopper. Prior programming experience is recommended, but not required. All students should exhibit careful attention to lab safety policies and the determination to test ideas through physical making and iteration.

Course Website: https://soa.cmu.edu/courses#graduate (https://soa.cmu.edu/courses/#graduate)

48-756 Project Planning and Reporting

Fall
The goal of this course is to expose the class to advanced project scheduling methods and familiarize the students with the primary reporting practices as performed in the construction industry such as change management, resource charts, and project status reports. The course objectives are as follows: 1. Outline and discuss the established practical approaches of planning and reporting; 2. Demonstrate the dynamic nature of construction projects stemming from inherent uncertainties. 3. Hone a student's adaptability to the dynamism of the process while delivering construction projects. This course will include both discussions on assigned topics and a studio-based collaborative group project. In order to provide a real-world experience to the students the second half of the semester will feature a group project focused on tracking a construction project with varying situational scenarios such as changes in resources and scope creep. Throughout the semester there will be one midterm and intermittent homework with the final deliverable being a "close out" document, which would essentially be a compilation of all the work during the semester projects.

Course Website: http://soa.cmu.edu

48-758 Responsive Mobile Environments (Grad)

Intermittent: 12 units
As part of this project-based course, we'll get hands-on with emerging technologies, concepts and applications in the Internet of Things through a critical lens. We'll prototype everyday intelligences and design smart and connected devices that examine and speculate on the strange, supernatural, and mystic qualities of the smart home. The first half of the semester will introduce students to building connected devices and intelligent spaces through technical development workshops, readings, applied explorations, and guest lectures. The second half of the semester will be organized as an applied collaborative project.

Course Website: http://rme2021.daraghbyrne.me

48-759 Value Based Design Introduction

All Semesters
This course will teach students the importance of Value Based Design across all project types and amp; delivery methods. The student will receive a firm grasp on the roles of each project stakeholder in a range of small to large construction projects.

Course Website: https://soa.cmu.edu/

48-763 Protean Systems: Sustainable Solutions for Uncertain Futures

Intermittent
Uncertainty perpetually plagues the built environment. The inability of our buildings and cities to adapt to shifting circumstances has led to an enormous amount of waste. Throughout the semester we will explore various types and scales of change and each week we will review various concepts such as Mass Customization, Computationally Responsive Environments and amp; Facades, Open Building, Shearing Layers of Change, Adaptive Reuse, Metabolism, Persistence, Preservation, Circular Economy, Design for Deconstruction and amp; Reuse (DfD+R), and Repair/Maintenance. To deepen our understanding of the concepts students will present group case studies each week and apply their understanding of the concept(s) to a project of their choosing as a design exercise or develop a detailed, individual case study report. Students in this course will: Compare many ways architects have attempted to deal with change in the past. Analyze the effectiveness of specific precedents over time. Diagram how anticipated and unanticipated forces of change impact architecture. Design innovative protean solutions of your own. The course welcomes students from all SoA and SoD undergraduate and graduate programs.

Course Website: https://soa.cmu.edu/courses#graduate (https://soa.cmu.edu/courses/#graduate)

48-764 BIM for architects: Leveraging Revit Parametric Design to Empower Innovative Arc

Fall
Building Information Modelling (BIM) has the potential to empower design by allowing architects to consider many design options, analyze the project while designing, and communicate the design to the client for feedback to allow an informed decision-making dialogue. The course will offer hands-on experience working with Autodesk Revit on an architectural BIM project. Students will gain the ability to leverage parametric abilities of Autodesk Revit program for a better preliminary design process. The course will focus on learning advanced parametric modelling techniques in Revit, and exploring analytic possibilities available for architects in early stages of the design: quantitative program area analysis, energy analysis, lighting analysis, initial cost analysis. This course is directed at graduate students, fourth and fifth-year undergrads are welcome as well. Basic knowledge of Revit modeling is required, either from 48485, 48568 (the Revit 3-unit section), 12711, or other background approved by the instructor.
Prerequisites: 48-485 or 48-568 or 12-711

48-770 Introduction to Machine Learning in Design

Spring
With the recent blooming of artificial intelligence (AI) and machine learning (ML) came a renewed interest in how these technologies may impact architecture and other creative practices. Introduction to Machine Learning in Design introduces students to this emerging field, giving them the tools to make their own machine-learning-based design tools by adapting state-of-the-art models, developing new models, and understanding how data shapes machine learning algorithms. Throughout this course, students explore two main fields of machine learning and their potentials in design and making problems: Unsupervised Generative Models, Natural Language Processing. Students will be introduced to the fundamental concepts of each field and get hands-on experience with state-of-the-art research and tools to implement them. Prospective students should have strong Python programming skills. Prior basic familiarity with Machine Learning is a plus. Taking Fundamentals of Programming (15-112) or school of architecture courses such as Design + Computation 1 or Scripting and Parametric Design before taking this course is strongly recommended but not mandatory.

Course Website: http://soa.cmu.edu

48-779 Processes of Digital Design Fabrication

Intermittent: 3 units
Digital Fabrication techniques are well established and widely used across all stages of design to production. Contemporary pre-occupations with materiality, ornament, digital craft, and surface topology are tethered to the affordances of these workflows and their direct connection to digital design methods. The impact of these processes reverberates across scales and around the globe, its presence undeniable. Off-site, prefabrication techniques are increasingly reliant upon computational methods to achieve greater control and precision, while recasting traditional design to production workflows. The architects traditional conveyor of design intent, the working drawing, and its conventions of plan and section are increasingly supplemented with machine and robot code. Meanwhile the jobsite and field construction of buildings remains a largely human endeavor, reliant upon the skill of local labor to assemble the many components that constitute a building to produce the one-off piece of architecture. This tension between the promise of the factory floor and the messy reality of the job site reflects the evolving nature of construction and its regimes of labor. Building construction is an industry in flux rooted in traditions that pre-date the emergence of computation, yet also in the midst of digital disruption as seen in advancements in onsite architectural robotic fabrication. Lest they succumb to greater marginalization, architects must engage these transformations and leverage their design affordances. Practitioners should be versed in the basic principles of digital fabrication and understand its affordances and potential influence upon the design process. Translations from drawing and model to building increasingly rely upon these modes of production. Emerging practitioners must be capable of engaging these modes of communication and leveraging these techniques in the realization of their design intent.

48-781 Spatial Analysis in Infrastructure Planning

Spring
A Geographic Information System (GIS) provides storage, retrieval, visualization, and analysis of geographically referenced data. GIS provides analytical tools to investigate spatial relationships, patterns, and processes of location-based data such as cultural, demographic, economic, environmental, health, physical, social, and other phenomena. GIS creates digital twins (virtual representations) of natural and built environments and integrates many types of digital models. GIS topics include geographic concepts (projections and map scales), map design, geodatabases (importing spatial and attribute data, geocodes, table joins, and data aggregation), spatial data processing, digitizing, data mining, multivariate cluster analysis, drive and walk time networking, raster GIS, spatial statistics (proximity and hot spot analysis), animation, and 3D GIS. CAFM (Computer Aided Facility Management) and IWMS (Integrated Work Management Systems) topics include space and asset management, building operations, environmental health and safety, and real property. The course includes in-person and asynchronous video lectures to learn important GIS concepts and a brief introduction to work management systems. Software tutorials cover leading GIS software from Esri Inc. Applications include ArcGIS Pro, ArcGIS Online, ArcGIS Map Viewer, ArcGIS Story Maps, and Dashboards. Subject areas are related to architecture, engineering, construction management, building performance, environmental health, sustainability, public policy, urban design, and planning.

Course Website: http://soa.cmu.edu

48-783 Generative Modeling (GRAD)

Fall and Spring: 9 units
This course introduces students to the fundamentals of generative modeling using computer aided design as practiced in the field of architecture. Core competencies will be developed through modeling projects and software intensive labs, while a broader critical framework for conceiving of contemporary and historical parametric practices will be encouraged through periodic lectures. Emphasis will be placed on careful consideration of digital mediums and developing a sense of craft related to digital modeling in the hope that students will become conscientious makers and consumers of digital content. Students will be encourage to understand and apply algorithmic problem solving to the many design constraints encountered in architecture. The course will explore the relationship of parametric workflows to design thinking and will situate contemporary trends in a broader framework of computational design. The course will also forefront complex form-making as a response to bio-mimicry, systems thinking, and mass-customization. Rather than positioning parametric modeling as a disruption of historical architectural design process, the course will encourage students to consider how new tools might augment the discipline's historical commitments to orthographic projection, perspectival drawing, and physical modeling.

48-786 Portfolio & Resume Preparation

Fall and Spring: 3 units
Portfolio is a unique document that showcases your professional and academic journey through various media and interfaces. Portfolio's capacity to represent a body of work and as a storytelling tool is emphasized in this course. The course proposes a fresh way of thinking about portfolio types and their content. Portfolio is a document through which you invite an audience to explore mediums of your creative thinking, forms of imagination, sense of materiality and possibilities of shaping the real conditions. The course deals with curating the content, editing your portfolio, resume, cover letters and work sample design. We shall look at myriad drawing types, layouts, typefaces and get into technicality of workflow, project sequence and details of the portfolio. In each session we shall select a particular content of the portfolio and discuss through presentations, diagrams, key references and students and amp;#39; work. Each project has its prompt, is unique in terms of its scale, modes of investigation and tools of representation. A successful portfolio shows diverse tools of thinking and communication.

48-788 Proseminar in Computational Design

Fall: 6 units
No course description provided.

48-795 LEED

Spring: 6 units
If you're interested in sustainable infrastructure and community design, have you considered how "green" strategies may vary around the world? Are there universal goals for the design of sustainable transportation, water systems or energy infrastructure, or must green goals and design approaches be adapted to a national or local context? 48795 A4, LEED, Green Infrastructure and Community Rating in Global Context, is a graduate level mini-course that compares global community and infrastructure rating systems to gain perspective about sustainable infrastructure development and community design. The course uses two rating systems and #8212;the US Green Building Council's Leadership in Energy and Environmental Design (LEED) Cities and amp; Communities Rating System and the Institute for Sustainable Infrastructure (ISI) Envision Rating Systemas springboards for exploration and discussion of other world rating systems that address these topics. We'll consider how the goals and implementation of a rating system may reflect the national context in which the system was created and discuss emerging issues that may be omitted from these rating systems. The course provides a foundation for taking USGBC's LEED Green Associate and/or LEED Accredited Professional exams, or the ISI Envision Sustainability Professional exam and is designed to hone your critical thinking about sustainable urban design and infrastructure development in a global context.
Prerequisite: 48-315

Course Website: http://soa.cmu.edu

48-801 Office Visits

Fall: 6 units
Each candidate will arrange with their home office a virtual 'visit' for members of the degree program and organize presentations of the projects, methodological challenges, recurring problems, best and worst practices within the context of their office experience. Asynchronous Course Delivery (Fall 2014) - and gt; September 18, through December 7, 2014 Online Synchronous Course Conclusion (Fall 2014) - December 8-11, 2014

48-802 Principles of Research I

Fall: 6 units
Candidate's current knowledge of problems, methods and outcomes based on their professional work. Overview of the eight knowledge areas as existing disciplines and their potential place in them. Asynchronous Course Delivery (Fall 2014) - and gt; September 18, through December 7, 2014 Online Synchronous Course Conclusion (Fall 2014) - December 8-11, 2014

48-803 Areas of Practice

Fall: 6 units
Candidate presentations of area(s) of expertise summarizing the methods and problems that are prevalent; using case studies to establish a situated approach to research. Asynchronous Course Delivery (Fall 2014) - and gt; September 18, through December 7, 2014 Online Synchronous Course Conclusion (Fall 2014) - December 8-11, 2014

48-804 International Exchange I

Fall: 12 units
Conduct workshops for collaborative research and information exchange meetings with EU cohorts visiting from the Universit and #233; Toulouse III - Paul Sabatier, Doctoral Programs in Architecture. Asynchronous Course Delivery (Fall 2014) - and gt; September 18, through December 7, 2014 Online Synchronous Course Conclusion (Fall 2014) - December 8-11, 2014

48-805 Directed Study I

Fall: 6 units
Prepare the first publishable article under the supervision of the advisor, based on the current professional practice record of the candidate. Submitted to a committee of faculty for approval. Asynchronous Course Delivery (Fall 2014) - and gt; September 18, through December 7, 2014 Online Synchronous Course Conclusion (Fall 2014) - December 8-11, 2014

48-809 International Exchange II

Spring: 12 units
Visit Universit and #233; Toulouse III - Paul Sabatier, Doctoral Programs in Architecture and participate in collaborative research and information exchange meetings with EU cohorts, based on the cohorts current knowledge base culled from their practice experience. Asynchronous Course Delivery (Spring 2015) - January 18, through May 13, 2015 and #8212; Online Synchronous Course Conclusion (Spring 2015) - May 14 through 17, 2015

48-810 Comparative Analysis of US and EU Practices

Spring: 6 units
Practices in the building sector vary considerably in the US versus the EU. The instructor will provide a rich collection of national and international initiatives in the AEC domains and include a stimulating series of site visits to important installations in the area. Asynchronous Course Delivery (Spring 2015) - January 18, through May 13, 2015 and #8212; Online Synchronous Course Conclusion (Spring 2015) - May 14 through 17, 2015

School of Art

Charlie White, Head
Location: College of Fine Arts 300
www.art.cmu.edu/ (http://www.art.cmu.edu/)

The School of Art’s undergraduate program bridges traditional studio practice with the experimental practices of new and unconventional media. The School offers two tracks for undergraduates—the Bachelor of Fine Arts (BFA) degree and the four interdisciplinary degrees collectively known as the BXA Intercollege Degree Program—along with a minor in art.

The program provides focused foundational instruction over the first year that builds toward a broad range of individualized study in the following three years. In their first year, students experience a wide array of intensive medium-specific studio courses, developing both technical skill and critical thinking. Following the completion of their foundation year, students direct their study across four primary concentrations with the freedom to pursue either in-depth study, hybrid study across concentrations, or specialized practices. Throughout the entire curriculum, the program emphasizes a conceptual approach to artmaking, challenging students to expand their ideas of artmaking and reconsider art’s possibilities.

The four primary concentrations are:

I. Drawing, Painting, Print Media, and Photography

II. Sculpture, Installation, and Site Work

III. Electronic and Time-Based Work

IV. Contextual Practice

Studio courses comprise over sixty percent of the course of study and academic courses comprise the remainder.

The School of Art occupies over 50,000 square feet of fabrication facilities, multi-purpose classrooms, media-specific studios and workshops, student and faculty studios, presentation rooms, and exhibition spaces, offering students access to both traditional and state-of-the-art tools. All juniors and seniors have dedicated, independent, 24-hour studio space.

The School’s distinguished faculty includes pioneers in computer animation and new media; artists and scholars exploring the complexity of queer thought and culture; and emerging practitioners confronting some of society’s most pressing issues. Throughout the program, these professors provide one-on-one support and feedback, helping each student foster an individualized artistic practice.

The program emphasizes an interdisciplinary approach to learning and art making, and students are encouraged to take advantage of the many resources of the College of Fine Arts and of the University. These include: the IDeATe network, the STUDIO for Creative Inquiry, the Miller Institute for Contemporary Art, and the Center for Arts in Society, among many others.

Graduates from the School of Art pursue diverse careers paths including traditional studio practice, animation, game design, positions with leading technology companies, and founding their own start-ups.

Using five categories of courses, the curriculum presents art-making in a unique manner which respects tradition and encourages innovation. The course categories are:

I . Foundation Courses
II. Intermediate Studios
III. Advanced Studios
IV. Critical Studies Courses
V. University Academic Courses

I. Foundation Courses

In their first year of study, students take a total of six foundation studio courses, exploring a range of mediums and conceptual processes. These studios ensure that all students have an exploratory experience with all of the media resources of the school. They also serve as preparation for intermediate and advanced studio work.

In addition, the Art First-Year Seminar introduces you to facilities, faculty, staff, resources, and many opportunities you can access within Art and the broader university. All first-year students take the seminar together, allowing you build a strong community that will help you develop as an artist during your time at CMU and beyond.

II. Intermediate Studios

Students take a minimum of six Intermediate Studio courses of their choosing in preparation for Advanced Studios in their junior and senior years. Intermediate studios will build on foundational knowledge and allow students to direct their studies to those mediums and topics most strongly of interest.

III. Advanced Studios

Students take a minimum of six Advanced Studio elective courses in their junior and senior years. These courses address specialized studio work in one of the four artistic concentration areas in the school, which are:

- Drawing, Painting, Print Media, and Photography (DP3)
- Sculpture, Installation, and Site Work (SIS)
- Electronic and Time-Based Work (ETB)
- Contextual Practice (CP)

In addition, students complete another six studio courses, which can be either Intermediate or Advanced Studios. This allows for significant exploration and integration across mediums within the program.

A minimum of four courses must be taken in one of these concentration areas. One of the intermediate or advanced courses can be a studio-based course within the College of Fine Arts, IDeATe, or additional programs.

IV. Critical Studies Courses

Students are introduced to critical studies in the spring of their first year, taking Foundations: Critical Studies. After the first year, students take four elective critical studies courses to broaden their knowledge and inform their studio practice. Critical Studies courses are discussion-based seminars examining theoretical texts in relation to periods of artistic practice. Readings will introduce students to the historical and critical background of the themes discussed in class and familiarize them with the varied methodologies and argumentative styles proper to art criticism, critical theory and philosophy.

V. University Academic Courses

Ten academic courses outside of Art and Computing @ Carnegie Mellon are required.

First Year

In the first year of study the student is expected to complete the following three requirements:

- Core@CMU (99-101)
- One First-Year Writing option
- One Global/Cultural Studies elective

For First-Year Writing, the student selects one of the two full-semester courses, (Interpretation and Argument (76-101) or Advanced First Year Writing: Special Topics (76-102)), or two of the three half-semester writing courses (Writing about Literature, Art and Culture (76-106), Writing about Data (76-107), or Writing about Public Problems (76-108)).

The Global/Cultural Studies electives include but are not limited to the following courses:

57-173	Survey of Western Music History	9
57-306	World Music	9
57-480	History of Black American Music	6
76-337	Intersectional Feminism	9
70-342	Managing Across Cultures	9
76-221	Books You Should Have Read By Now	9
76-232	Introduction to Black Literature	9
76-239	Introduction to Film Studies	9
76-241	Introduction to Gender Studies	9
76-386	Language & Culture	9
79-145	Genocide and Weapons of Mass Destruction	9
79-201	Introduction to Anthropology	9
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9

79-205	20th Century Europe	9
79-208	Witchcraft and Witch-Hunting	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-234	Technology and Society	9
79-240	Development of American Culture	9
79-242	African American History: Reconstruction to the Present	9
79-244	Women in American History	9
79-245	Capitalism and Individualism in American Culture	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-263	Mao and the Chinese Cultural Revolution	9
79-265	Russian History: Game of Thrones	9
79-266	Russian History and Revolutionary Socialism	9
79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-275	Introduction to Global Studies	9
79-280	Coffee and Capitalism	9
79-283	Hungry World: Food and Famine in Global Perspective	9
79-343	Education, Democracy, and Civil Rights	9
79-345	Roots of Rock & Roll	9
79-350	Early Christianity	9
79-377	Food, Culture, and Power: A History of Eating	9
80-100	Introduction to Philosophy	9
80-250	Ancient Philosophy	9
80-251	Modern Philosophy	9
80-253	Continental Philosophy	9
80-254	Analytic Philosophy	9
80-276	Philosophy of Religion	9
82-xxx	Any Languages, Cultures, and Applied Linguistics course	

After First Year

The student must take one course in each of the following academic areas or “options”:

- Humanities and Languages or “Culture Option”
- Math, Science, Computer Science and Engineering or “Technical Option”
- History, Psychology, Economics or “Social Science Option”

The student must then take at least three additional courses from one of the academic areas/options listed above.

Finally, the student must take two additional, but unspecified, academic electives.

In selecting courses for the university academic component of the curriculum, students are encouraged to complete a cluster of courses that appeals to and develops their interests as emerging artists. In the process of taking their university electives, students can often simultaneously earn a minor.

Bachelor of Fine Arts (B.F.A.) Curriculum

Minimum units required for B.F.A. in Art 384

Below is the recommended distribution of courses in the four-year B.F.A curriculum. After the freshman year, students may begin to choose university electives. After the first semester of the sophomore year, students have more options regarding the sequencing and selection of their coursework.

First Year

Fall		Units
60-104	Foundations: Art First-Year Seminar	6
60-110	Foundations: Time-Based Media	10
60-131	Foundations: Sculpture	10
60-150	Foundations: Drawing	10
76-10X	First-Year Writing	9
99-101	Core@CMU	3
		48

Spring		Units
60-101	Foundations: Risk, Agency, Failure	10
60-107	Foundations: Critical Studies	9
Select two of the three Foundation Media Courses:		20
60-120	Foundations: Digital Media	
60-135	Foundations: Sculpture II	
60-170	Foundations: Paint/Print	
xx-xxx	Cultural/Global Studies elective	9
		48

Second Year

Fall		Units
60-2xx	Intermediate Studio Elective	10
60-2xx	Intermediate Studio Elective	10
60-2xx	Intermediate Studio Elective	10
60-3xx	Critical Studies Elective	9
xx-xxx	Academic Elective	9
		48

Spring		Units
60-200	Sophomore Review	0
60-2xx	Intermediate Studio Elective	10
60-2xx	Intermediate Studio Elective	10
60-2xx	Intermediate Studio Elective	10
60-3xx	Critical Studies Elective	9
xx-xxx	Academic Elective	9
		48

Third Year

Fall		Units
60-xxx	Intermediate or Advanced Studio Elective	10
60-xxx	Intermediate or Advanced Studio Elective	10
60-xxx	Intermediate or Advanced Studio Elective	10
60-3xx	Critical Studies Elective	9
xx-xxx	Academic Elective	9
		48

Spring		Units
60-xxx	Intermediate or Advanced Studio Elective	10
60-xxx	Intermediate or Advanced Studio Elective	10
60-xxx	Intermediate or Advanced Studio Elective	10
60-3xx	Critical Studies Elective	9
xx-xxx	Academic Elective	9
		48

Fourth Year

Fall		Units
60-401	Senior Studio	10
60-4xx	Advanced Studio Elective	10
60-4xx	Advanced Studio Elective	10
xx-xxx	Academic Elective	9
xx-xxx	Academic Elective	9
		48

Spring		Units
60-402	Senior Studio	10
60-4xx	Advanced Studio Elective	10
60-4xx	Advanced Studio Elective	10
xx-xxx	Academic Elective	9
xx-xxx	Academic Elective	9
		48

Sophomore Reviews

Students give an overview of their work at the midpoint of their four-year course of study. At the end of the sophomore year, students undergo a faculty review of their work to date in the program.

Art Majors Minoring or Double Majoring in Another Department

About a third of current B.F.A. Art students pursue a minor or a second major. If students are contemplating this option, they must discuss their plans with academic advisors from the minor or second major department as well as with the School of Art academic advisor.

Study Abroad

Art students are encouraged to spend either a semester of their junior year, or a summer before or after their junior year, in one of many available international programs. These programs include university sponsored and exchange programs in which a student's financial aid package remains in effect, and programs sponsored by other institutions.

Programs with other Pittsburgh Institutions

Art students are eligible to take courses at the nearby University of Pittsburgh's History of Art and Architecture Department, and at the Pittsburgh Glass Center. Established agreements with these institutions and other Pittsburgh colleges, universities or centers offer cross-registration opportunities at no additional expense to the student.

BXA Intercollege Degree Programs

BACHELOR OF COMPUTER SCIENCE AND ARTS (BCSA)

BACHELOR OF ENGINEERING STUDIES AND ARTS (BESA)

BACHELOR OF HUMANITIES AND ARTS (BHA)

BACHELOR OF SCIENCE AND ARTS (BSA)

Carnegie Mellon University offers a degree program that combines an Art Focus (12 courses) with a focus in the College of Engineering, the School of Computer Science, the Dietrich College of Humanities and Social Sciences, or the Mellon College of Science. The Assistant Head of Academic Affairs in the School of Art advises BXA majors in selecting courses in the Art Focus. A description of these three programs, and a list of requirements and electives, can be found in the in the BXA Intercollege Degrees Program section (p.) of this catalog.

Art Minors

Students from other colleges and departments are eligible to pursue a minor in art. A minor requires six courses in the School of Art, selected from a list of requirements and electives as described in the Minors Offered by the College of Fine Arts section (p. 209) of this catalog.

Master of Fine Arts (M.F.A.) Degree

The School of Art offers a three-year program leading to a Master of Fine Arts in Art. This is a unique program designed to connect art-making to the university at large, and to Pittsburgh communities and organizations. Information about this program is available at the School of Art website (http://www.art.cmu.edu/mfa/overview/).

Master of Arts Management (M.A.M.) Degree

The College of Fine Arts and the Heinz College School of Public Policy and Management co-sponsor a Master of Arts Management degree. Students admitted to the M.A.M. degree program in their junior year may complete both a Bachelor of Fine Arts degree and a Master of Arts Management degree in five years. Students interested in this graduate degree should consult with advisors early in their undergraduate program.

Pre-College Program

The School of Art offers a Summer Pre-College Program, with both three- and six-week options.This program is designed to prepare the college-bound high school student for college level work in art. Information is available at the Summer Pre-College site (https://www.cmu.edu/pre-college/).

Full-Time Tenure Track Faculty

LYNDON BARROIS JR., Assistant Professor of Art – MFA, Washington University in St. Louis; Carnegie Mellon, 2020–

KIM BECK, Associate Professor of Art – M.F.A., Rhode Island School of Design; Carnegie Mellon, 2004–

ELIZABETH CHODOS, Assistant Professor of Curatorial Practice, Director of Miller Institute of Contemporary Art – M.A., School of the Art Institute of Chicago; Carnegie Mellon, 2017–

JOHANNES DEYOUNG, Assistant Professor of Art – M.F.A., Cranbrook Academy of Art; Carnegie Mellon, 2018–

ISLA HANSEN, Assistant Professor of Art – M.F.A., Carnegie Mellon University; Carnegie Mellon, 2019–

RANEE HENDERSON, Assistant Professor of Art – M.F.A., Bard College; Carnegie Mellon, 2023–

KATHERINE HUBBARD, Assistant Professor of Art – M.F.A., Bard College; Carnegie Mellon, 2019–

ANDREW JOHNSON, Associate Professor of Art – M.F.A., Carnegie Mellon University; Carnegie Mellon, 2004–

JONGWOO JEREMY KIM, Associate Professor of Art History and Theory – Ph.D., Institute of Fine Arts at New York University; Carnegie Mellon, 2018–

LING-LIN KU, Assistant Professor of Art – M.F.A., University of Texas at Austin; Carnegie Mellon, 2022–

GOLAN LEVIN, Professor of Art – M.S., Massachusetts Institute of Technology; Carnegie Mellon, 2004–

CLAYTON MERRELL, Dorothy L. Stubnitz Professor of Art – M.F.A., Yale University; Carnegie Mellon, 1998–

PAOLO PEDERCINI, Associate Professor of Art – M.F.A., Rensselaer Polytechnic Institute; Carnegie Mellon, 2009–

RICHARD PELL, Associate Professor of Art – M.F.A., Rensselaer Polytechnic Institute; Carnegie Mellon, 2008–

MELISSA RAGONA, Associate Professor of Visual Culture and Critical Theory – Ph.D., State University of New York at Buffalo; Carnegie Mellon, 2003–

BRITT RANSOM, Associate Professor of Art – M.F.A., University of Illinois at Chicago; Carnegie Mellon, 2022–

SHARMISTHA RAY, Assistant Professor of Art – MS/MFA, Pratt Institute; Carnegie Mellon, 2023–

JON RUBIN, Professor of Art – M.F.A., California College of Arts and Crafts; Carnegie Mellon, 2006–

SUZIE SILVER, Professor of Art – M.F.A., The School of the Art Institute of Chicago; Carnegie Mellon, 1999–

CHARLIE WHITE, Regina & Marlin Miller Head, Professor of Art – M.F.A., Art Center College of Design; Carnegie Mellon, 2016–

ALISHA WORMSLEY, Assistant Professor of Art – M.F.A., Bard College; Carnegie Mellon, 2024–

IMIN YEH, Assistant Professor of Art, Director of Foundational Studies – M.F.A., California College of the Arts; Carnegie Mellon, 2016–

Full-time Joint Appointments

JAMIE GRUZSKA, Special Faculty and CFA Photography Administrator – M.F.A., University of Buffalo;

DYLAN VITONE, Associate Professor, School of Design – M.F.A., Massachusetts College of Art; Carnegie Mellon, 2006–

Visiting Faculty

MARIA ELENA VERSARI, Visiting Professor of Art History and Theory – Ph.D., Scuola Normale Superiore;

Research and Teaching Faculty

YOKO SEKINO-BOVÉ, Assistant Teaching Professor of Art – M.F.A., University of Oklahoma; Carnegie Mellon, 2023–

School of Art Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

60-101 Foundations: Risk, Agency, Failure

Spring: 10 units
Foundations: Risk, Agency, Failure is a transdisciplinary research-based studio course introducing you to the many ways that artists challenge conventions, experiment, and take risks through their artwork. The class will have theory-driven prompts with no specific medium requirements, and encourage you to explore the wide range of approaches to making that constitute artistic research. You will explore foundational questions like: What can art uniquely do in the world? How can you playfully work with subjects and materials that are foreign and unfamiliar? How do you define success as an artist? How do you embrace failure as a productive part of the artistic process? How do you become comfortable breaking and remaking rules in art? The class will set up a structure for you to explore productive failure, encouraging you to take risks in a supportive environment and ultimately help you explore their own agency as cultural producers in the world.

60-104 Foundations: Art First-Year Seminar

Fall: 6 units
Foundations: First-Year Seminar is a critical aspect of beginning your experience as a School of Art Student. This course introduces you to the school's many facilities, equipment, opportunities, staff, and faculty that will be essential resources for you throughout your four years at CMU School of Art. You will build community with your entire first year cohort, both BFA and BXA students, as you share 24 hour access to the Foundations Studio, a multi-use shared studio space that will support your studio coursework during your first year. Through lectures and panel discussions, you will explore various methods of artistic research and forms of making that support today's creative citizens. Through hands-on demonstrations, you will learn technical skills and gain access to equipment that will prepare you for academic and artistic success at CMU and beyond.

60-105 Cultural History of the Visual Arts

Spring: 9 units
Have you ever felt that you liked an artwork but couldn't explain why? Do you have questions about art that you were always afraid to ask? This course is conceived to give students the tools to feel at home when visiting a museum and talk about art in social, business and academic settings. It is organized over two semesters, but students can take only one of the two courses. Cultural History of the Visual Arts I (in the fall) covers the period from the 1500s to the 1800s and features masterpieces and lesser known works in Western and Non-Western art, organized chronologically and by theme. Some of the topics we will study include the controversy surrounding Leonardo's and Michelangelo's works, the role of censorship in the arts, the development of perspective experiments and visual theories from Antiquity onward, the concept of landscape and the status of the artist in the Ming dynasty, the impact of colonialism and post-colonial identity in South American Art, the rediscovery of Pompeii and Herculaneum and the Egyptian craze in the 1800s, the world of Opera and ballet, and the Impressionists' ideas of what an artwork should be. The course also includes museum visits that will be organized taking in consideration the students' schedule. No prerequisite required and open to students from all disciplines.

60-106 Cultural History of the Visual Arts - the Modern Period

Spring: 9 units
Have you ever felt that you liked an artwork but couldn't explain why? Do you have questions about art that you were always afraid to ask? This course is conceived to give students the tools to feel at home when visiting a museum and to talk about art in social, business and academic settings. It is organized over two semesters, but students can take only one of the two courses, or both, in any order they prefer. Cultural History of the Visual Arts -The Modern Period (offered in the spring) covers the period from the 1800s to the 2000s and features masterpieces and lesser-known works that define our idea of what art is and what role it has in society. Some of the topics we will study include the invention of a "modern" ways of seeing in Japanese art; the impact of science, film and photography on the Impressionists; the myth of the artist as a savage, a fool, and a prophet; the creation of ideal homes for common (and uncommon) people; the meaning of the avant-garde; and the many ways in which artists and politicians experiment with art and architecture in order to control our minds and emotions. The course also includes museum visits that will be organized in relation to the students' schedules. No prerequisite required and open to students from all disciplines.

60-107 Foundations: Critical Studies

All Semesters: 9 units
Foundations: Critical Studies is a seminar course that expands your historical knowledge concerning contemporary art and human experience in society. Through critical reading and writing, you will learn how the role of artistic research contextualizes the conceptual creativity of your studio practice. This course involves close reading and discussions of a wide range of texts, from foundational theory to short stories, nonfiction, poetry, exhibition reviews, artist interviews, curatorial essays, and excerpts from scholarly monographs. Today's visual artist will find that writing is a key to future professional opportunities and that research, writing, and theory are integral parts of artmaking. This course integrates analytical reading and research-based writing into your creative process.

60-110 Foundations: Time-Based Media

Spring: 10 units
Foundations: Time Based Media introduces you to audio and video production software, equipment and techniques into your interdisciplinary studies in art. Projects explore the making and critiquing of moving-image and audio across a variety of contexts, and takes an active approach in learning how to produce your own new media work using both standard and experimental production techniques. You will build comprehension of related histories and theories; explore the meanings and consequences of ubiquitous broadcast and social media; and learn how to interrogate and wield media paradigms to challenge their influences in our lives.

60-120 Foundations: Digital Media

Spring: 10 units
Foundations: Digital Media is a practical introduction to expanded modes of creative practice made possible by the computer. In this studio course, you will develop the skills and confidence necessary to produce interactive, generative, and immersive artworks; discuss your work in relation to current and historic praxes of electronic art; and engage new technologies critically. Topics will include no-code and low-code approaches to: internet art, immersive world-building, and environmental storytelling; generative art and experimentation with learning machines; creative interventions and performance in social platforms; and the development of branching narratives and games.

60-125 IDeATe: Introduction to 3D Animation Pipeline

Fall and Spring: 12 units
This class will explore computer animation as it pertains to a professional animation production pipeline. The course is designed to give students exposure to key job descriptions that align to the animation industry. Topics covered include: character design, world building, storyboarding, digital sculpture, look development, rigging, layout, animation, cinematography, lighting, and rendering. These topics are taught in 2-4 week sprints that allow a student to learn the fundamentals of each craft. In a mixture of class lectures, critiques, and training workshops, students will become acquainted with the necessary skills needed to create their own characters and animations. By completion of the course, students will be familiar with industry-standard best practices and ready to take advanced courses related to animation, vfx, and video game related pipelines. This course specifically offers insight on how the craft of animation is always evolving at top studios such as Walt Disney Animation Studios, Pixar, and Industrial Light and Magic.

Course Website: http://cmuanimation.weebly.com/

60-126 Introduction to Performance Capture and Rendering

Intermittent: 6 units
[IDeATe course] This mini is designed for those interested in the growing world of performance capture and visual effects. Utilizing the advanced motion capture facilities at Carnegie Mellon and the Kinect, students will learn how to capture motion from performance and apply it to CG characters and objects. While this technique is found in many video games and vfx movies, it has the ability to create endless possibilities within the realm of computer graphics and experimental animation/art. Students will also become more familiar with the process of rendering to create the necessary polish for their animations/visualizations. CG Lighting, camera work, and material shading are just a few of the many topics covered in this course.
Prerequisites: 15-104 Min. grade C or 62-150 Min. grade C

60-128 IDeATe: Real-Time Animation

Fall: 10 units
An introductory course that explores improvisational strategies for making animation within real-time computer graphics frameworks. Advancements in motion capture technologies, real-time 3D computer graphics engines, and visual programming tools for AV synthesis provide open frameworks for the exploration of animation in spatial and interactive contexts. Studio work will explore real-time animation in a variety of contexts, including screen-based interaction, site-specific installation, and spatial immersion. Conceptual frameworks drawn from the histories of video art, animation, and immersive media design will inform collaborative group work and class discussion. Students without the prerequisite may register by instructor permission.

60-131 Foundations: Sculpture

Fall: 10 units
Foundations: Sculpture I is an introductory studio course in concepts, techniques, and tools for the fabrication of three dimensional physical works. The studio course introduces both digital and physical fabrication methods to translate ideas and materials into 3D forms. We will cover measuring, drawing, planning, pattern making, and construction techniques for cardboard, fabric, recycled materials, and a variety of mixed media; as well as the use of additive materials like paper clay. Through technical demonstrations, assignments, and hands-on explorations, students will learn how to make use of equipment in our sculpture labs such as laser cutters, sewing machines, and a variety of hand tools. Concepts explored as a group include physical and sensorial properties such as scale, weight, and materiality; as well as deconstruction / disassembly, reconstruction / reassembly , transformation, translation, function, dysfunction, and utility. Our experiments will prompt us to consider relationships between objects, bodies, spaces, and society; as well as between technology, craft, form, and language; ultimately exploring how to use the making of 3D objects as both a communicative tool and a practical tool for life. No prior knowledge or experience in the field is required to take this course. No prior knowledge or experience in the field is required to take this course.

60-135 Foundations: Sculpture II

Spring: 10 units
Foundations: Sculpture II is an introductory studio course in concepts, techniques, and tools for the fabrication of three dimensional sculptural works in wood and metal. This studio course introduces physical fabrication methods to translate ideas and materials into 3D forms. We will cover measuring, drawing, planning, subtractive and additive processes, joinery techniques for wood and metal, and a variety of materials in combination with these construction techniques. Through technical demonstrations, assignments, and safe hands-on explorations, students will learn how to use equipment located in our woodshop and metal shop, including major saws and sanders, hand tools, metal saws, and MIG welders. This class will explore concepts and histories related to functional object-making and utility; as well as sculpture in relation to space and site. Through presentations, readings, and class dialogue, students will be introduced to contemporary artists working across 3D physical media and installation, with special attention to the relationship between idea and materiality. Our experiments will prompt us to consider relationships between objects as architectures, bodies, spaces, and society; as well as between technology, craft, and language; ultimately exploring how to use the making of 3D forms as a communicative tool.

60-136 Ceramics for Non-Majors

Intermittent: 10 units
An introduction to three-dimensional form in clay, with access to our ceramics facility and kiln firings. Skills covered include hand building, sketching and modeling for larger fireable clay forms, throwing on the wheel, and basic glazing techniques. Discussions will include contemporary artists working in ceramics, as well as historical examples, and various approaches and techniques for working in clay.

60-137 Physical Computing for Non-Majors

Intermittent: 10 units
TBA

60-141 Black and White Photography I

Fall and Spring: 10 units
This course will teach you the basic craft of photography from exposure of the negative through darkroom developing and printing to print finishing and presentation. Content includes student presentations, class discussions, shooting assignments, darkroom sessions and class critiques. We will concentrate not only on the technical aspects of photography, but also the aesthetics of seeing with a camera. The course concentrates on photography as a fine art and #8212; what is unique to it and the concerns that are shared with other visual arts, such as composition, tonal values, etc. and aims to equip students with an understanding of the formal issues and the expressive potentials of the medium. Use your own 35 mm camera, or borrow one from us for the semester. Students are responsible for the cost of photo paper and film, and a lab fee is charged for the course.

60-142 Digital Photography I

Fall and Spring: 10 units
This course explores digital photography and digital printing methods. By semester's end students will have knowledge of contemporary trends in photography, construction (and deconstruction) of photographic meaning, aesthetic choices, and the use of color. Students will learn how digital cameras work, proper digital workflow, RAW file handling, color management and Adobe Photoshop. Through the combination of the practical and theoretical, students will better define their individual voices as photographers. No prerequisites.

60-150 Foundations: Drawing

Fall: 10 units
Foundations: Drawing is a vital foundation for your interdisciplinary studies in art. This course will concentrate on the traditional elements of drawing and design: structure, line, shape, texture, motif, gesture, value and composition. You will be introduced to figure drawing, portraiture, perspective, and media experimentation. By the end of the semester, you will understand the importance of drawing as a visual language as well as a means of thinking. You will be expected to expand your mindset of what constitutes drawing and apply skills, knowledge and ideas from other studio classes and academic studies to your work.

60-170 Foundations: Paint/Print

Spring: 10 units
Foundations: Paint/Print introduces you to color, paint, printed multiples, and digital imaging to expand upon the techniques, concepts and materials used in contemporary two dimensional image making. You will work predominantly in drawing and painting (water based media), but will also have opportunities to experiment with screen printing, risograph, image transfers, and digital output. With an emphasis on material exploration, you will investigate how scale, medium, and color support or distract from the intention of your artwork. You will think about how contemporary artists do visual research in our image and media saturated world, and what it means to appropriate, collage, produce memes, and/or publish in multiple media. Working in multiples and in series, you will practice working iteratively, producing deeper visual exploration of your artistic concept and intention.

60-200 Sophomore Review

Fall and Spring
Students present their work and their ideas about their work to a faculty committee. A successful review is required for advancement to the junior year. Although this is a non-credit course, it is required of all Art (BFA, BHA, BSA, and BCSA) sophomores.

60-201 Intermediate Studio: Social Practice

Fall: 10 units
In recent years, socially-engaged art projects that invite exchange, imagine new social relationships, and provoke individual and collective action have gained increasing prominence. These projects can double as a barter network, a walking tour, a residency program, a protest, or even a post-natural history museum. Rather than being the result of a solitary artist working within an isolated studio, social practice projects are driven by the desire to connect, to look outside oneself in meaningful and tangible ways, and to impact daily life within specific communities. Through the production of work that intersects with a variety of publics, students in this class will use their art practice as a means for directly engaging with the world around them.

60-203 Intermediate Studio: Museum as Resource

Intermittent: 10 units
This course, held within the Carnegie Museum of Art, will explore the museum as a resource for research, experimentation, and development. Students will investigate the ways museums can intersect with their creative disciplines and fields of study, and look at how its unique combination of internal and external assets can be utilized within their practice. We will look beyond the museum as a platform for exhibition and programing, and instead consider its functionality as a classroom and a laboratory. We will approach our time in this course as a research residency, prioritizing exploration and idea development. We will study the history of museums as sites of research for humanities, arts, social sciences, and STEM, and consider how as community art spaces, they're also sites of wonder and play. There will be readings, presentations, class discussions, visits from museum staff and working artists, and creative projects. Students will collaborate but also work toward the development of an individual project.

60-204 Futures

Intermittent: 10 units
In Futures, students will be asked the question, "what if?" Looking backwards and forwards students will grapple with what futures might be possible, impossible, desirable, undesirable and more. Throughout the class, students will explore critical and imaginative world-making and utopian, dystopian, and ambiguous scenarios from a variety of perspectives through the act of making. In addition to speculating and inventing futures, students will explore various histories of the future - through mythologies, origin stories, science fiction, futurist movements across cultural contexts, and more. Students will respond to theory-driven prompts and are encouraged to take risks and explore a variety of different approaches to art-making, as each assignment will not have a specific medium requirement.

60-208 Alternative Photography: Contemporary Antiquarian Printmaking

Intermittent: 5 units
This course will explore alternative photographic techniques and concepts in an effort to extend the boundaries of the photographic image. Through the course we will investigate contemporary digital imaging techniques and apply them to turn-of-the-last-century hand-applied emulsions. Subjects covered are digital imaging, digital negative printing and workflow, hand-applied emulsions, alternative uses of Polaroid photography, and concepts and theory of the still image. As we move through the course we will also consider the theory and history of photography and create images that are not standard in today's imaging practices. A diverse range of contemporary photographic work will be presented to increase students' visual awareness and understanding of the possibilities inherent in the medium. Through work/review sessions, students will evaluate their own ideas and judgments in pursuit of a well-communicated image.

60-211 Intermediate Studio: Sound + Vision - Intro to Audiovisual Art

All Semesters: 10 units
Sound + Vision is an introduction to the analysis and making of visual music, music video, expanded cinema and sound design for moving image media. Through presentations, screenings, demos and workshops students will study the influences of sound on the perception of space and time, and the impact audiovision has on our experience of moving image media. Working on their own and in small groups, students will complete short sound experiments and develop a variety of audiovisual projects.

60-212 Intermediate Studio: Creative Coding

Intermittent: 12 units
This is an intermediate level course in "creative coding": the use of programming and computation within the context of the arts. Ideal as a second course for students who have already had one semester of elementary programming (in any language), this course is for you if you'd like to use code to create art and #8212; AND you're already familiar with the basics of programming, such as for() loops, if() statements, objects, and arrays. Students will develop or deepen the skills and confidence to produce interactive, generative, and computational artworks; discuss their work in relation to current and historic praxes of computer art; and engage new technologies critically. Through rigorous programming exercises, students will develop mastery over the basic vocabulary of constructs that govern static, dynamic, and interactive form, with the aim of applying these skills to problems in creative explorations of transmediality, connectivity, generativity, and immersivity.

60-213 Intermediate Game Studio: Real Time 3D

Intermittent: 10 units
Game Studio: Real Time 3D is a hands-on intermediate course focused on immersive environments, world building, character creation, and real time experiences at the boundaries of gaming. On a conceptual level we'll look at practices within digital art and independent game development: virtual architecture and sculpture, walking simulators, avatar-based performances, and other playable media. On a technical level the course will introduce you to 3D modeling for real time applications (using Blender) and game engine workflows (using Unity) as a scaffolding for advanced courses. Students will work individually. Experience with game engines and 3D modeling is not required.

60-214 Photography and the Narrative of Place

Intermittent: 5 units
This half-semester course will use photography to develop understandings of our surrounding environments. Students will choose a single location to work in, photographing and researching its function in the community, its history, and its relationship to broader concepts and similar spaces. Weekly assignments will require students to work with a variety of photographic methods to construct a narrative that derives meaning from the complex connections between people, objects and the spaces they inhabit. Throughout the course, students will strengthen their understanding of the ways in which these tangible and abstract elements of our environments work together through in-class exercises, weekly discussions and critiques. The course work will culminate in a portfolio of the completed project. The class will study work and books by notable and emerging figures in the medium, including Robert Adams, Carolyn Drake, Roy DeCarava, Rinko Kawauchi, Alec Soth, Carrie Mae Weems, Zoe Strauss, Gregory Halpern, and Susan Lipper. Required readings will include essays and short stories by Wendell Berry, Rebecca Solnit, Teju Cole, Joan Didion, and Georges Perec.

60-216 Animated Storytelling:

Intermittent: 10 units
This course offers an interdisciplinary exploration of the interrelationships between literary and cultural productions, and the art of animation. It combines traditional humanities research in literature, history, and religion with contemporary digital humanities and visual storytelling techniques. Topics offered under this title include "Chinese Mythology and Animation" and "Chinese Ghost Stories and Shadow Play". "Chinese Mythology and Animation": In addition to close reading and critical examination of Chinese mythological tales, their social, historical and cultural origins and modern adaptations, this course also encourages students to create their own "mythological stories" through creative writing, animation, digital storytelling, and immersive media projects. "Chinese Ghost Stories and Shadow Play": Through reading and analysis of the 17th-century literary masterpiece, Strange Tales from a Chinese Studio, this course examines the mystical and often overlooked world of Chinese ghost literature and culture. Through practical studio work, students will explore techniques in traditional Chinese shadow play in relation to a broad cultural survey of world heritage shadow play traditions and contemporary media arts affordances. Students are encouraged to create their own ghost stories using various mediums.

60-217 Intermediate Studio: Experimental Hybrid Film - Video and Animation

Intermittent: 10 units
Digital production and post-production technologies have made hybrid moving images that combine live action, animation and image processing ubiquitous. Collage aesthetics and processes are present even in moving image media that appear naturalistic. While developing proficiency in Adobe After Effects and other production and post production tools, students explore the experimental world-building and storytelling possibilities of hybrid moving image media production. The course is structured around technical tutorials and workshops, screenings/discussions, and the creation of hybrid films combining animation, live action, and 2D/3D art. Artists whose work we will look to for inspiration include Yuge Zhou, Shana Moulton, Tabita Rezaire, Rachel MacLean, Chitra Ganesh, Jee Young Lee, Sondra Perry, Miwa Matreyek, Saya Woolfalk, Jacolby Satterwhite, Nunavut Animation Lab, Alex DaCorte, Grace Nayoon Rhee, Nam June Paik, Wangechi Mutu, Joo Young Choi, Cecile B. Evans, Ryan Trecartin, Oskar Fischinger, Karel Zeman, Sin Wai Kin, Winston Hacking, Russ Murphy (RUFFMERCY), Jordan Belson and many others.

60-218 IDeATe Portal: Real-Time Animation

Fall: 10 units
An introductory course that explores improvisational strategies for making animation within real-time computer graphics frameworks. Advancements in motion capture technologies, real-time 3D computer graphics engines, and visual programming tools for AV synthesis provide open frameworks for the exploration of animation in spatial and interactive contexts. Studio work will explore real-time animation in a variety of contexts, including screen-based interaction, site-specific installation, and spatial immersion. Conceptual frameworks drawn from the histories of video art, animation, and immersive media design will inform collaborative group work and class discussion. Students without the prerequisite may register by instructor permission.

60-219 Intermediate Studio: Stop-Motion Animation

Spring: 10 units
This intermediate animation studio explores principles and techniques of stop-motion animation. Students will explore a range of materials and methods through hands-on animation studio practice. Coursework emphasizes creative content production, experimentation, critical thinking, and collaboration. Pioneering works of historical avant-garde animation inform exercises and project prompts, drawing upon rich global histories and a wide spectrum of practitioners. A combination of rigorous studio practice, historical exposition, and theoretical discourse will equip students with the practical techniques and critical tools required to advance new dimensions in stop-motion animation. Studio work emphasizes collective productions that engage the principles of animation, material sensitivities, and expressive puppetry performance. Historical and theoretical examples guide coursework and class discussion. Screenings, practical tutorials, readings and discussions, will expose students to historical frameworks and contemporary currents in stop-motion animation, equipping students with a variety of conceptual, methodological, and technical resources.

60-220 IDeATe: Technical Character Animation

Fall: 10 units
Technical Character Animation is a deep dive into the fundamental concepts of character animation and "The Illusion of Life." This course will focus on building a foundation of body mechanics that demonstrate weight, balance, and authenticity. Through a series of strategically designed modules, students will gain a command of the 12 principles of animation, beginning with a ball bounce to more advanced block, spline, and polish workflows. This course is designed to give students exposure to the art of movement as it is done by animators in the fx, film, and game industries.

Course Website: http://tcacmu.weebly.com/

60-221 Intermediate Studio: Animation Workshop

Intermittent: 10 units
This is an open animation studio for students who want to improve existing animation skills and develop a personal animated short. The class will introduce a variety of techniques and concepts for animation production. Using both 2D and 3D tools, animation will be explored through short assignments designed to develop diverse skills and ideas. Each student will develop and produce a short animation. The class will engage in discussion and critique of each other's work along with examples of historic and contemporary animation.

60-222 Intermediate Studio: Digital Animation

All Semesters: 10 units
This is an open animation studio for students who want to improve existing animation skills and develop a personal animated short. The class will introduce a variety of techniques and concepts for animation production. Using both 2D and 3D tools, animation will be explored through short assignments designed to develop diverse skills and ideas. Each student will develop and produce a short animation. The class will engage in discussion and critique of each other's work along with examples of historic and contemporary animation.

60-223 IDeATe Portal: Introduction to Physical Computing

Fall and Spring: 10 units
This practical project-based course covers the basic technical skills (including electronics, programming, and hardware) needed to build simple interactive objects with embedded behavior using the Arduino microcontroller. A sequence of projects challenge students to apply their technical skills in creative ways. For the final project, the class works with a local group of older people who serve as design clients; students conjure and build them functioning custom interactive assistive devices of a practical or whimsical nature. Sensor inputs covered include an ultrasonic ranger, thermometer, light sensor, and human inputs like buttons and knobs; outputs to affect the world include actuators such as motors, LED lights, speakers, and haptic feedback devices. This introductory portal course has no technical prerequisites. Readings and guest speakers address topics including design, disability, and aging. See courses.ideate.cmu.edu/60-223/s2018/work for examples of prior student projects. Contact rzach@cmu.edu with any questions about the course. Students are encouraged to also take the micro course 99-353 IDeATe CAD and Laser Cutting.

Course Website: https://courses.ideate.cmu.edu/60-223 (https://courses.ideate.cmu.edu/60-223/)

60-224 Intermediate Game Studio: Interactivity

All Semesters: 10 units
Game Studio: Interactivity is a hands-on intermediate course focused on innovative and expressive forms of play, game design, and interactive storytelling. Structured as a series of short assignments, the class will involve the radical transformation of ordinary games into meaningful, original, or even impossible artworks, as well as the creation of narrative experiences at the boundaries of gaming. The course will cover basic elements of game design, common programming patterns in game development, and code-less game-making tools. Students will mostly work individually. No programming experience is required.

60-225 Intermediate Studio: Drawing with Machines

Intermittent: 10 units
This is an intermediate studio course in experimental drawing, generative art, computational design, and mechatronic mishegoss. Working at the boundaries of creative code, automation, physical materials, and gestural mark-making, we will explore personal and peculiar new approaches to digital imaging; the development of ultra-niche workflows as a mode of creative practice; and the use of algorithms and machine collaborators as nontraditional intermediaries between mind, hand, and paper. Drawings will be created using AxiDraw plotters and a variety of other specialized robots. Interested students should have JavaScript and/or Python programming experience equivalent to an introductory course such as 15-104, '110 or '112.

60-230 Intermediate Studio: Metals

Fall: 10 units
This course explores a variety of contemporary and traditional approaches to metal fabrication metal with a focus on hot and cold connecting mechanisms. Basic and intermediate metal fabrication techniques will be covered in this class, other sculptural media and connecting strategies will be developed on an as needed basis to accommodate individual projects and inquiries. Students will participate in self-directed research, assigned topic presentations, reading and group discussions, field trips, in addition to hands-on assignments and projects. Students can also incorporate additional non-metal materials of their choice to their projects. The goal for this course is to develop a stronger understanding of metal, it's history and role in the contemporary art in order to broaden your visual and material languages when build forms and to choose to put your sculptures together through deep and meaningful ways. It is recommended that a foundations sculpture course be completed as a prerequisite for this class.

60-232 Intermediate Studio: Interactive Objects

All Semesters: 10 units
Interactive Objects is an intermediate sculpture course that explores the concepts, techniques, and tools behind making interactive, responsive, or kinetic art works using physical computing and basic robotics. This studio course introduces students to building circuits, programming with arduino and processing, and integrating human-computer and human-object interaction into sculptures and installations. Through technical demonstrations, assignments, and hands-on explorations, students will build circuits, experiment with various sensors and actuators, program microcontrollers, re-wire existing electronics, and better understand electrical current and conductivity in order to harness it to create responsive elements and motion. Students in this course will be given priority access to the tools and equipment in our physical computing lab, as well as learn how to integrate these tools with our other digital fabrication facilities, including laser cutters and 3D printers, as well as our soft sculpture lab. Students will be expected to do technical assignments as well as individually-motivated self-driven projects based on research and ideas they find personally interesting and compelling. Our research, experiments, and projects will prompt us to consider the relationship between the digital and the physical; as well as the relationships between objects, bodies, technologies, spaces, cultures, and societies. No prior knowledge or experience in the field is required to take this course.

60-233 Intermediate Studio: Soft Sculpture

Intermittent: 10 units
Soft Sculpture is an intermediate studio course that explores the concepts, fabrication techniques, and history behind the creation of sculptural works of art made with fabric, fibers, and soft materials. In this class, we will discuss and demonstrate intermediate sewing and seaming techniques; pattern-making and pattern-following techniques for shapes, experimental forms, and garments; needle-felting and wet felting for wool; loop and cut pile tufting; inkjet printing on fabric; and some basics of weaving, and / or knitting / crochet, as well as embroidery, all with special attention to combining both hand-making and digital techniques when applicable. Projects in this class may include, but not be limited to: fabric forms with armatures; inflatables; stuffed forms; puppets and kinetic soft sculpture; wearables / garments / costumes; woven, tufted, or embroidered tapestries and quilts; and a variety of other experimental soft sculptures. As a class, we will discuss and share relevant art historical and contemporary examples of artists and artworks making use of fabric and fibers, as well as relevant texts and theory. Concepts explored as a group include the transformation of 2d pattern to 3D form; relationship of wearable works to the body and performance; the history of fabric and fiber craft in relationship to gender studies and underrecognized craftspeople; and ideas surrounding transformation and the relationship between craft and technology.

60-234 Intermediate Studio: Ceramics

Intermittent: 10 units
This course is a comprehensive introduction to the craft of ceramic art. Students will investigate clay as an art material for personal expression. The primary emphasis is on studio work leading to a portfolio of finished pieces by the end of the semester. The goal of this course is that students will be able to create expressive, three-dimensional clay forms with the proper understanding of the materials and process. The topics include, but are not limited to, various construction techniques such as soft and hard slab, pinch, coil, and wheel-throwing. Also, surface treatment techniques such as texturing and underglaze painting will be introduced. Discussions will include contemporary artists working in ceramics as well as historical examples and various approaches and techniques for working in clay.
This course will consist of demonstrations and lectures, research/writing assignments in and out of class, as well as work time. Students will develop a body of work within the context of the projects to express their individual voice. This course requires students to participate in critiques to analyze their own and others' work and identify strengths and weaknesses while promoting artistic growth and the exchange of ideas. No prior experience in clay is required.

60-236 Intermediate Studio: Mixed Media

All Semesters: 10 units
How Do Things Connect? Even when a sculpture may appear to be made with a single material there are often complex connections between many elements that are intended to either be visible or invisible. How do physical connections between materials and objects affect our visual experience? Can the ways pieces connect create or reinforce meaning in an object? Might you need to invent your own forms of joinery for a sculpture? This class focuses on a variety of contemporary approaches to making mixed media sculpture with an emphasis on how things connect both physically and conceptually. Students will learn a wide range of techniques for assembling dissimilar materials including hot and cold metal joints, wood joinery, adhesives and kinetic and flexible joints. Basic metal fabrication and intermediate wood constructing techniques will be developed on an as needed basis to accommodate individual projects and inquiries. Through in-class practice, assignments, research, presentations, readings, and critiques students will take on self-directed projects that explore how things connect in a deep and meaningful way. The goal for this course is to develop a stronger understanding of materials in order to broaden your options when considering how you choose to put your sculptures together. Connections between parts are just one more aspect of developing your own personal visual language. It is recommended that a foundations sculpture course be completed as a prerequisite for this class.

60-237 Intermediate Studio: Electronic Sculpture

All Semesters: 10 units
Interactive Objects is an intermediate sculpture course that explores the concepts, techniques, and tools behind making interactive, responsive, or kinetic art works using physical computing and basic robotics. This studio course introduces students to building circuits, programming with arduino and processing, and integrating human-computer and human-object interaction into sculptures and installations. Through technical demonstrations, assignments, and hands-on explorations, students will build circuits, experiment with various sensors and actuators, program microcontrollers, re-wire existing electronics, and better understand electrical current and conductivity in order to harness it to create responsive elements and motion. Students in this course will be given priority access to the tools and equipment in our physical computing lab, as well as learn how to integrate these tools with our other digital fabrication facilities, including laser cutters and 3D printers, as well as our soft sculpture lab. Students will be expected to do technical assignments as well as individually-motivated self-driven projects based on research and ideas they find personally interesting and compelling. Our research, experiments, and projects will prompt us to consider the relationship between the digital and the physical; as well as the relationships between objects, bodies, technologies, spaces, cultures, and societies. No prior knowledge or experience in the field is required to take this course.

60-240 Unfolding Environments: The Intersection of Person and Place

Intermittent: 10 units
In this course students will use photography to develop projects that study our social environments and personal landscapes. This studio explores the ways photography can combine form and concept to derive meaning from place. Students will be assigned two projects for the semester. The first will be a brief study of a familiar space. The second will comprise the remainder of the semester, concentrating on a single location of the student's choosing. Students will photograph and research their chosen place's function, its history, and its relationship to broader concepts and comparative spaces. A series of prompts, readings, lectures, and critiques will help students build their project and develop new ways to approach their subject matter as they create a long-form narrative.

60-241 Black and White Photography II

Fall and Spring: 10 units
Black and White Photography II continues developing your technical skills in analog photography by introducing medium and large format cameras and prints. Large format view cameras remain the state of the art in control and quality in both film and digital photography. These cameras as well as unusual panoramic and pinhole cameras will be supplied. This course emphasizes aesthetic development and personal artistic growth through individual tutorials and group critiques, and will help to build professional level photography skills. Additional topics include digital printing and negative scanning, advanced monotone printing methods, and a focus on exhibition and folio presentation. Students are responsible for the cost of photo paper and film, and a lab fee is charged for the course.
Prerequisites: 60-141 or 62-141

60-242 Digital Photography II

Intermittent: 10 units
Digital Photography II combines digital and analog processes in both color and black and amp; white. Students will gain experience with digital workflow, analog to digital conversion, virtual drum scanning and large format digital printing. Topics include trends in contemporary photography, professional practices, project development, narrative and serial work, and portfolio presentation. Students will be expected to develop their own self-directed projects throughout the semester culminating in a cohesive portfolio of their work. Readings, assignments, artist visits, critiques and discussions will give context to the practical work and help develop a wide ranging familiarity with the subjects.
Prerequisites: 60-142 or 60-141 or 62-142 or 62-141

60-244 Contemporary Photo Theory

Intermittent: 9 units
Because, you know, the photographs are more a question than a reply. (Sebastiao Salgado) A photograph is a moral decision taken in one eighth of a second, or one sixteenth, or one one-hundred-and-twenty-eighth. (Salman Rushdie) This seminar investigates current topics in photography and the image; our goals are twofold: identification of photo theory as it applies to current practice from both the viewpoint of maker and consumer. The course is designed to address philosophical issues for photographers working now and will favor conversation over written work; students are expected to fully participate in critical analysis and discussions. Readings include works by Roland Barthes, Stephen Shore, Susan Sontag, Hollis Frampton, John Szarkowski, Robert Adams, Italo Calvino, Berenice Abbott, John Berger and James Elkins. No pre-requisites.

60-245 Portrait Photography

Intermittent: 10 units
Portraiture maintains a unique standing in photography for its direct and collaborative relationship between an individual and a photographer. This course will examine this relationship and the larger contexts which provide the conceptual framework for deriving meaning and understanding from an image of another person. We will study the theoretical and practical aspects of portrait photography in both studio and environmental settings, providing students with an understanding of the genre by developing both technical and conceptual skill sets. Students will utilize analog and digital equipment, learn studio lighting techniques, develop approaches to working with natural light, and explore methods of printing and presentation. Students will gain knowledge in the development of portraiture through the work of notable figures in the medium's history and contemporary field, including August Sander, Dorothea Lange, Walker Evans, Dawoud Bey, Milton Rogovin, Rineke Dijkstra, Zoe Strauss, Susan Lipper, Justine Kurland, Stefan Ruiz, Larry Sultan, Carrie Mae Weems, Roy DeCarava and Alec Soth. Class discussions, readings and critiques will provide an outline for completing both single and serial image assignments.

60-250 Intermediate Studio: Painting

Fall: 10 units
This course serves as an introduction to technical, conceptual and historical practices of painting. Through a variety of painting experiences and presentations using oil media, students progress from observational exercises and exposure to materials and techniques to developing personal processes, imagery and ideas. Class sessions include technical demonstrations, illustrated lectures, personal and group critiques.
Prerequisites: 60-157 or 60-150

60-251 Intermediate Studio: Print Media

Fall: 10 units
Printmaking is a process based medium that produces multiples of original artworks. Students will create four works on paper using the following printmaking approaches: Relief (carved), Intaglio (engraved), Lithography (planographic), and Screen Printing (stencil). Each technique's unique set of materials, processes and aesthetics will be explored. This course focuses on traditional tools and processes, but will include utilization of digital images and sources through a critical lens. While primarily focused on the learning of fundamental techniques, the class will also also expose students to ways that Print Media can be a tool (physically and conceptually) in contemporary practice. Open to sophomores in the School of Art, or by instructor permission.
Prerequisites: 60-157 or 60-150

60-252 Intermediate Studio: Color

Intermittent: 10 units
In this course, students will learn to employ a wide range of color theories and color systems through hands-on exercises and studies. Studies will be done primarily in paint, with some use of collage and digital media. These exercises will be aimed at mastering a variety of color approaches that will be applicable to each student's own artistic practice. Students will develop, based on their own interests, a cohesive body of work in which to practice and expand on the skills learned through the directed exercises. Studio work will be augmented by lectures, demonstrations, critiques, readings and critical discussion of writings about color.

60-253 Intermediate Studio: Fundamentals of Figuration

Intermittent: 10 units
This studio-based figuration course is designed to introduce students to the fundamentals of the figure. This class will provide a solid understanding of how to begin working with the human form in space. Students will learn how to block out and establish the major structural masses of the body through gesture drawing. We will learn to look "through" the body, understanding its logical underpinnings through rigorous study of anatomy and physiology, both by lecture and observation. Students will work from the skeleton, draw and paint musculature, and spend extensive time working from the live model or models. Both dry and wet media are encouraged: graphite, charcoal, metal point, colored pencils, pastels, ink, watercolor and gouache can be openly explored in this course.

60-254 Intermediate Studio: Photography

Intermittent: 10 units
A photograph captures a moment of time and freezes it in place. In this introductory course, students will reflect on their own lives, capturing people, places and things, through portraiture, interior space, landscape and still lifes. We will consider the formal qualities of light, composition, color, sequencing, editing and print as we take, shape and print our own digital photographs. The course will be framed by field trips, readings, discussions and presentations that look at how artists make photographs.

60-255 Intermediate Drawing Studio: Trails of Touch

All Semesters: 10 units
We will emphasize technical aspects of traditional and performative drawing that is the compulsion to leave tangible traces of our presence. The sensual interaction of body as instrument in contact with a surface will be explored and analyzed as we develop our perceptual, conceptual and imaginative skills. Experimentation in and devotion to our studio practice will extend our capabilities and heighten our sensitivity to a diverse range of materials and methods of mark making and rendering. Scratching, scraping, scoring, caressing, stroking, burnishing, brushing, dragging, wiping, scrubbing and erasing are some of the means through which we will record our observations, thoughts and feelings on a wide range on substrates. Formal presentations, technical demonstrations, visiting lectures, museum trips, and film screenings complement studio time devoted toward independent and class projects. Material fee for reduces cost for special papers and supplies like silver point, traditional gesso, large paper rolls etc.

60-258 Intermediate Studio: Screenprint

Intermittent: 10 units
This course is a comprehensive and intensive study of Serigraphy (screenprinting), one of the most versatile and contemporary of printmaking techniques. The course is focused upon the mastery of this process. Students will explore multiple methods of image making (from hand-drawn to digital imaging) and will be introduced to CMYK printing. The emphasis of this course is on artistic work on paper, but will also be exposed to the ways that screenprint can work across a wide range of different media: from 2D (paper, canvas, cloth) to 3D (book forms, sculpture, installations) and utilizing printed multiples in participatory and exchange based artworks.

60-260 Intermediate Studio: Imaging

Fall: 10 units
TBA

60-263 Intermediate Studio: Graphic Novel

Intermittent: 10 units
In this course, students will critically and creatively engage with the medium of comics to learn how to better communicate their ideas in this format as well as challenge its boundaries. A substantial portion of the course will focus on familiarizing students with the basics of storytelling in a sequential narrative format and creating opportunities for students to discover, hone and explore their own voice and style. In addition to creating new work, students will also explore the history of comics and the origins of the "modern" graphic novel. Students will also be exposed to both graphic and non-graphic artists whose works has challenged and redefined the genre. We will explore these artists in order to understand how our own work borrows from and draws upon a rich lineage. Students will also be expected to think beyond the commonly accepted notions of comics and to question the relevancy of their work in this medium. Finally, each student will produce a new body of work that will culminate in the production of a 4-5 "page" "sequential" narrative.

60-276 Photography and the Ephemeral

Intermittent: 10 units
Photography and the Ephemeral is an interdisciplinary photography course designed for students of various disciplines interested in exploring the relationship between images and the ephemeral: things that last only a short moment in time. Throughout the semester students will explore different themes and ways to approach ephemeral imagery such as; still lifes, installations, performances for the camera, and the short-lived nature of images both physical and digital. Participants explore these themes through weekly presentations, discussions, assignments, and critiques.

60-277 Constructing Meaning with Photographs

Intermittent: 5 units
Constructing Meaning with Photographs will discuss ways in which multiple images can be used to expand upon and clarify the intended message of individual photographs and a visual series in whole. Throughout this half-semester studio course, students will work through a variety of approaches to image sequencing and editing. At the start of the course, students are expected to have a significant body of completed work or an easily accessible archive of print resolution images (100+ images) to work with for out of class assignments. Using their archive, they will edit sequences for different presentation methods including gallery exhibitions, books and zines, websites, linear displays, and print portfolios. Weekly in class editing exercises will conceptually correspond with out of class assignments to allow for experimentation and conversation around different approaches to photographic sequencing. Lectures, readings, guests, exhibition visits, and book presentations will provide additional support for understanding how to use photographs in series to build meaning.

60-278 Infinite Rooms: Photography and Installation

Intermittent: 10 units
Infinite Rooms is an interdisciplinary photography course designed for students of various backgrounds interested in exploring the relationships between place, images, and installation. This course will investigate the methodologies of how a place is documented, constructed, and imagined in photographs. This class will introduce a critical survey of images, films, and texts from artists who work at the intersection of installation and images. Throughout the semester various prompts will introduce different frameworks for thinking about photography and installation, such as the dramatic; the psychological; and the personal. Students will utilize digital and analog equipment, learn how to use a large-format view camera, learn studio lighting techniques, develop approaches to working with natural light, and explore methods of printing and presentation.

60-279 Photography and the Ineffable

Intermittent: 10 units
This course explores the relationship between photography and the indescribable, intangible, and hard-to-see. From the spiritual, to the sublime, to the abstract; we will review different frameworks for thinking about the ineffable and how it relates to photographic work. Students will explore these themes through weekly presentations, discussions, assignments, writing workshops, and critiques. We'll look at artists who think critically about photographic representation and investigate a heightened sensorial interpretation of the world. This class will encourage experimental methods and approaches to photography.

60-333 IDeATe: Animation Rigging

Spring: 10 units
Animation Rigging explores processes for building digital skeletons and control systems to drive computer animated forms. This course investigates vital techniques and concepts to create expressive, fully articulated characters for computer animation, film, and game production. Beginning with rigging fundamentals, coursework will advance through various systems and methods that are needed to convey motivated movement and expression in a variety of character forms. Certain key topics include kinematics, joint orientations, driven keys, direct connections, space switching, corrective blend-shapes, custom attributes and graphic user interfaces (GUIs), skinning and deformation. Additionally, coursework provides an introduction to scripting methods for rig creation, including expressions, Python, and MEL. Students will be provided a valuable range of tools that meet production standards for animated film and game creation, as well as a necessary conceptual framework to enable complex problem solving at all levels of rig creation. Anyone interested in the artistic and technical sides of computer animation are encouraged to enroll. Previous experience with Autodesk Maya/3D animation is preferred.

60-335 IDeATe Special Topics in Animation: Story Development

All Semesters: 6 units
IDeATe Special Topics in Animation: Story Development provides insight and strategy for animated storytelling in film and media production. This mini- studio seminar draws upon diverse historical examples to highlight storytelling strategies across cultures and production paradigms. Over this seven-week course, students will develop their own original stories in the forms of scripts and pitch packets, to be later produced as animated content. Discussion and critique will cultivate storytelling skills with greater understanding for audience, form, and cultural context, providing essential tools for communication through animation.

60-337 IDeATe Special Topics in Animation: Storyboarding

All Semesters: 6 units
IDeATe Special Topics in Animation: Storyboarding focuses on the translation of stories and ideas into sequential image boards for animation. This mini-studio seminar exposes the visual grammar of filmic storytelling through analysis and production of storyboards and animatics. Over this seven-week course, students will develop their own original storyboards and animatics to be later produced as animation. Analysis of historical examples will reveal strategies for storytelling through sequential narrative and animation. Discussion and critique will cultivate storytelling skills with greater understanding for audience, form, and cultural context, providing essential tools for communication through animation and design.

60-343 Professional Practices in Photography

Intermittent: 10 units
This studio course will introduce students to the working methods of professional photographers and artists. For the first half of the course students will develop a substantial body of visual work. They will then use that work in the second half of the semester to produce portfolios across a variety of media (digital, print, web, exhibition, etc.). Throughout the process they will develop skills in constructing and completing projects, cultivate their personal vision and aesthetic tastes, explore methods of disseminating their work to larger audiences, establish time management and planning around long form projects, and acquire an understanding of the marketing, outreach and community building necessary for working artists to build and sustain a career.
Prerequisites: 62-141 or 60-141 or 62-142 or 60-142

60-350 Professional Development for Creative Practices

Fall and Spring: 9 units
This course is intended to expose students studying in creative fields to the basic principles, skills and functions of business used every day in creative practices and industries. Supporting a creative practice - whether an individual studio practice, a temporary collaboration or commission, or an incorporated business or non-profit - all require a foundational knowledge of basic organizational, legal, and financial structures and practices. Throughout this seminar-style course, students can expect to develop a starting knowledge of basic business concepts; learn a foundational understanding of ethics and best practices in business; develop problem-solving skillsets and methodologies for managing creative projects and programs; and practice applying these learnings to their own creative practices. Topics covered will include, but are not limited to: basic business structures; intellectual property; Contracts and employment; methods for generating income and fundraising; financial management and taxes; marketing and communications; negotiation and compromise; and elements of business strategy development. This course assumes no prior background in business education or administration experience.

60-351 Entering the Artworld: Mapping a career path in an uncharted artworld

Intermittent: 9 units
Building a career as an artist is a nuanced endeavor that looks different for each individual. Unlike other fields, where a set professional structure ushers graduating students into a career, the artworld is self-navigated. This course gives artists a foundational understanding of the multifaceted profession they are entering, where they will learn about key support structures like museums, commercial galleries, DIY spaces, residencies, and much more. They will also train in a wide range of concrete skills, including writing artist statements, creating a network, building an online presence, and pricing an artwork. The goal of this class is to give students the awareness, skills, and resourcefulness they need to chart their own course as a studio-based fine artist in an artworld that's ever-changing.

60-352 NOISE: Toward a Critical Theory of Sound and Hearing

Intermittent: 9 units
This seminar will explore audio art in its widest sense: sound sculpture and installations, radio art, the soundtrack, just about anything audible but not conceived as music. Special focus on the production (and reception) of sound by artists, amplifying those creative efforts that, in having explored acoustics, soundscapes, and listening, might also serve to inspire students to incorporate sound in their own work. Contemporary critical theory, by and large, is still glaringly silent on aurality and auditory phenomena; it seriously fails to consider sound as an object of study, instead focusing quite exclusively on visual culture (film, TV, video, computer screens, which are, of course, technologies of vision and sound). This seminar will address this roaring silence by examining some suggestive but disparate theoretical work related to sound and by engaging with a range of artistic practices that explore the production and reception of sound itself.

60-353 Critical Studies: Media Performance - History, Theory, and Contemporary Practice

Intermittent: 9 units
During the last decade of the twentieth century, new technologies have transformed the way we think about live performance. By examining the use of media (analog and digital) across the areas of sound/music, dance, theater, performance art, gaming, and installation, this course will traverse multiple theories and practices of performance history. With an eye to how changing theories of performativity have influenced how artists think about what it means to "perform," this seminar, in a sense, will be engaged in both philosophical and aesthetic research about how technology has changed the conventions of performative artistic practice. What was the role of technology in the dematerialization of the object of art? How have ideas about virtual, parallel worlds changed the way artists think about the "performing body?" If technology once acted as a prosthetic device, increasing an artist's sensual and perceptual world, what happens to the role and impact of an artist's work in the seemingly inert realms of programming or the increasingly autonomous areas of Robotic Intelligence? What does art look like in a post-internet age?

60-356 Critical Studies: Once Upon A Time: A Survey of International Fairy Tale Film

Intermittent: 9 units
Fairy tales have been a part of cinema from the very beginning. Since George M and #233;li and #232;s' 1899 Cinderella, filmmakers from around the globe have continuously returned to the genre not only for escape into enchanted worlds, but also for social critique, with stories of injustices avenged, class oppression overthrown and gender roles expanded. This course decenters the conception of the genre fixed by Disney and Hollywood to examine fairy tale films from around the world. We will encounter a poetics and politics of wonder in international films about transformation, wish-fulfillment and reversals of fortune that deliver a situated counterpoint to the hegemony of a colonizing and commercialized poetics of magic. The transformative power of fairy tales can be approached from a variety of perspectives. We will analyze how stories themselves function as shape-shifters, morphing into new versions of themselves as they are retold and as they migrate into other media. Beyond looking at the films as texts we will consider the affective qualities of how their formal and aesthetic aspects create wonder, delight, humor, anxiety and terror. What are the stakes of the fairy tale's varied transformations today, for whom? In this class we will watch and discuss films, stories and historical and critical texts. Films screened and discussed include: Kwaidan (Japan, 1964), To Sleep With Anger (USA, 1990) El Laberinto del Fauno (Mexico-Spain, 2006), Green Snake (Hong Kong, 1993), Peau d'Âne (France, 1970), Tropical Malady (Thailand, 2004) Sampo (Finland/Soviet Union, 1958) and many more. Assignments include: short written responses to the films and readings, study group activities, and one collaborative creative research project.

60-357 Critical Studies: Nation's Nature - Art, Environment and the American Landscape

Intermittent: 9 units
This course will explore how representations of the American landscape create an ever-shifting national identity. Slogans like "Make America Great Again" trade on nostalgia and a desire for a fixed narrative but ignore the experience of marginalized groups. The actual environment, meanwhile, is being destroyed by the same people who use it as a symbol of power and purity. From painting to photography, print, animation, sculpture and social practice, we will consider how art has fueled or challenged nationalism, patriotism, American exceptionalism. Readings in historical texts, narrative essays and cultural geography, along with discussions and presentations will provide art students a broader context for their own research.

60-359 Critical Studies/Adv. ETB: Playful theory: critical topics in game culture

Intermittent: 9 units
This hybrid seminar course combines games studies, game criticism, and research-based art to examine the history, contexts, and frontiers of play. Digital and analog games will be approached through a variety of lenses: games as culture, systems, technologies, commodities, etc. While not geared toward the technical development of videogames, the coursework will include creative projects beyond writing and discussion. The goal is to provide conceptual tools to enrich your design/art practice and tackle a variety of academic topics in a playful but rigorous way.

60-362 Critical Studies: Art Writer: Writing as Object, Criticism, and Experiment

Intermittent: 9 units
ART WRITER will strive to bring together the intersecting discourses of artists' use of writing as an object, exploring experiments by artists, poets, novelists and critics who use language and theory as invention. The idea of experiment implied here emphasizes the urgency that art writing moves beyond its own history, beyond the received understanding of its proper practices in order to propose new modes of critical reflection. The form and material force of language will be explored through the conceptual and critical work of Harryette Mullen, Fatimah Asghar, Jamaica Kincaid, Ta-Nehisi Coates, Frances Stark, Kathy Acker, Samuel Delaney, Trisha Low, Glenn Ligon, Brian Kim Stefans, Pajtim Statovci, Tan Lin, Adam Pendleton, just to name a few. International projects of Art and Language, Fluxus, the Dark Room Collective, Los Contempor and #225;neos, as well as more recent iterations will be investigated/researched. This is a writing intensive seminar with experimentation at its core. Members will workshop their writing: revise, rethink, perform, and publish.

60-364 Critical Studies: Decolonize Now!

Intermittent: 9 units
This course explores ways to "delink" artmaking and its history from the "colonial matrix of power." Examining critical discourses surrounding decoloniality, as well as post-coloniality, students will test and complicate foundational concepts such as hybridity, empire, migrant subjectivity, consciousness of the Borderlands, post-occidental reason, pluriversality, and transmodernity. Over the duration of the semester, students will be tasked to form a corroborated viewpoint of their own in relation to theoretical texts by Walter D. Mignolo, Frantz Fanon, Okwui Enwezor, Gloria Anzaldúa, Rey Chow, Hamid Dabashi, Gayatri Chakravorty Spivak, Rob Nixon, Michael Hardt and Antoni Negri, Edward Said, Homi Bhabha, Paul Gilroy, and others. Artists under consideration may include H and #233;lio Oiticica, Walid Raad, Tavares Strachan, MLT Collective, John Akomfrah, Dahn Vo, Trinh T. Minh-ha, Lubaina Himid, Jimmie Durham, Jeannette Ehlers, Martine Gutierrez, Coco Fusco, Lorraine O'Grady, Judy Baca, and ASCO. Exhibitions such as The Other Story: Afro-Asian Artists in Post-War Britain (1989-90), All the World's Futures, Venice Biennale (2015), Verboam and #233;rica (2017), Decolonizing Appearance (2018), Memories of Underdevelopment: Art and the Decolonial Turn in Latin America, 1960-1985 (2018), May You Live In Interesting Times, Venice Biennale (2019), The Warmth of Other Suns: Stories of Global Displacement (2019), and When Home Won't Let You Stay: Migration through Contemporary Art (2019) are crucial in understanding the framework of this class. Remember Anzaldúa's words: Because I, a mestiza, continually walk out of one culture and into another, because I am in all cultures at the same time, alma entre dos mundos, tres, cuatro, me zumba la cabeza con lo contradictorio. estoy norteada por todas las voces que me hablan simult and #225;neamente.

60-365 Critical Studies: Queer Power in Art Theory

Intermittent: 9 units
Queer power is a form of (anti-)knowledge that demystifies phallogocentrism and neuters heteronormativity. This class examines how queer theories empower - and can originate in - art making and its history. Over the course of the semester, students discuss recent publications in the field such as Rogers Brubaker's trans: Gender and Race in an Age of Unsettled Identities (2016) and Paul B. Preciado's Testo Junkie: Sex, Drugs, and Biopolitics in the Parmacopornographic Era (2013). Students also investigate recent exhibitions exemplifying oppositional epistemology such as Trigger: Gender as a Tool and a Weapon (The New Museum, 2017-18) and Hide/Seek: Difference and Desire in American Portraiture (National Portrait Gallery, 2011). Interweaving the canons of queer thoughts with newer voices such as Lee Edelman, Tim Dean, and Maggie Nelson, this class contextualizes Paul Mpagi Sepuya, Tschabalala Self, Wu Tsang, and other artists who embody queer power today.

60-369 Critical Studies: DEEP FAKE, AI and Beyond: Posthumanism & Contemporary Art

All Semesters: 9 units
Is Post-humanism just another kind of humanism? Is the idea of difference at risk when thought is no longer attached to a body? What are the possibilities of imagining a queer phenomenology - or a transhumanism that challenges the limits placed on gendered, sexualized, racialized and so-called "able" bodies? How are our concepts of affect and authenticity being transformed by ideas of robotic and artificial intelligence? What are the various forms of subjectivities generated by machine-learning enabled media? How are constructions of "cheapfakes," "shallowfakes," and "deepfakes" posing ethical dilemmas in information and world-making landscapes? This seminar hopes to excavate such questions and many more produced by examining the competing and shared perspectives developed by contemporary artists and critical theorists across posthumanist, transhumanist and new materialist paradigms.

60-372 Critical Studies: The Precarious Body in Contemporary Art

All Semesters: 9 units
This seminar will examine images and projects in contemporary art that deal with debates concerning ideas that had already begun brewing in the 1980s and early 90s, that addressed issues of institutional violence circulating under the guise of "discourse," or that delved into ideas of difference and alterity through the notion of "abjection." More recently, the idea of precarity has taken central stage as a way of thinking through, and taking action against, the kinds of structural oppression that deems certain groups of people vulnerable to repeated forms of aggression, poverty, illness, and displacement without protection. We will also explore a seemingly opposite corollary: the SUPERCLEAN a trope that exploits the capacity of certain technologies to present hygienic forms of representational violence at the level of the digitally manipulated image. We will read the work of Tung-Hui Hu, Zuzana Kovar, Judith Butler, Claudia Rankine, Pamela Lee, Frantz Fanon, Sarah Ahmed and study the projects generated by artists, such as Lygia Clark, H and #233;lio Oiticica, Superflex, Anicka Yi, Mika Rottenberg, Carolyn Lazard, Katherine Behar, Trisha Baga, Hito Steyerl, among others, as a way of interrogating these State mandated structures of material and psychic repression. A major part of the course will examine how contemporary artists responded, acted, and producedaddressing the precarious body as the site for political and aesthetic resistance.

60-374 Critical Studies: Picturing Asian America

Intermittent: 9 units
Asian American art is not Asian art. Asian art is not Asian American art. The conditions in which we make art in the United States have always been unique: our art has evolved to be antiracist, anti-patriarchal, and for the sake of the undercommons. Expanding oppositional consciousness, the historical context for our exploration and inquiry is enriched by Asian American literature and film; we welcome and renew the lessons of our shared minor feelings. This class also celebrates the Asian American history of collaboration with other BIPOC (Black, Indigenous, and People of Color) communities and the tradition of intersectional artmaking against the hegemonic canon.

60-378 Critical Studies: Science Fiction Film

Intermittent: 9 units
Science Fiction Cinema offers an idiosyncratic survey of the science fiction film genre. More than just a form of entertainment, science fiction is a powerful tool for exploring our hopes, fears, and dreams about the future. This class reveals how science fiction films often grapple with philosophical and ethical questions about the nature of humanity and our place in the universe. Together we will explore how filmmakers have used the science fiction film genre to explore both the timeless human condition and the complex issues of their time. In addition to studying the films themselves, we will consider the various cultural, social, political, and technological contexts in which they were created as well as how the films have themselves influenced society and culture. Additionally, we will examine the creative and technical innovations that filmmakers use to create stunning and thought-provoking works of art. Throughout the course, we will watch and analyze a variety of science fiction films, from international and independent productions like "World on a Wire", "Stalker" and "Advantageous" to blockbuster and studio productions like "Nope", "The Wandering Earth" and "The Matrix". Through weekly readings, film screenings, and class discussions, students will learn to analyze film as a creative medium of social commentary and critique. Assignments will include personal written responses to the films and readings, visual essays, and creative projects.

60-384 Critical Studies: Ecstatic Experience: Experimental Film & Video History/Theory

All Semesters: 9 units
"An Ecstatic Experience" is the name of Ja'tovia Gary's six-minute film made in 2015 that takes the idea of "ecstasy" and flips it on its head implying a radical reversal of pain and suffering into an affirmation of resistance and freedom. This seminar focuses on complex, risky experiments within both historical and contemporary practices of experimental video and filmmaking in which ideas about the ecstatic are explored across filmic and new media materiality, immersion, duration, sound design and mark-making. Reaching back to the kinds of ecstatic models used during the sixties and seventies, fluctuating between feverish dream-states, psychedelic trips, orgiastic burlesques, impassioned revolutionary plans (Nam June Paik, Paul Sharits, Ben Van Meter, Carolee Schneemann, Kenneth Anger, Stan VanDerBeek, Black Audio Film Collective), and racing forward to the legacy of that period, we will view and discuss a vast range of artists, such as New Red Order, Wu Tsang, Peggy Ahwesh, Leslie Thornton, Kevin Jerome Everson, Ja'tovia Gary, Cauleen Smith (just to name a few). Questions we will explore include: What does it mean to experiment? How have temporal, spatial and political parameters shifted? What new models have problematized and replaced earlier ecstatic models of media-inspired social change and experimentation?

60-385 Crit. Studies: Visual Pleasure - Patterning & Ornamentation in Contemporary Art

All Semesters: 9 units
In his influential essay, "Ornament and Crime," Adolf Loos questioned the use of ornaments based on a notion of progressive history, in which the past is subordinated to the future. Modernism universalism coated as purity and functionalism relegated notions of excess to the past, along with it, visual pleasure, ornamentation, patterning, and the use of saturated color in art, architecture, and design. This course focuses on the recovery of color, patterning, and ornamentation in contemporary art led by non-western, women, queer, and/or BIPOC artists as a resistance to western 'order' which deems these aesthetics 'primitive,' 'feminine,' and 'irrational.' We will use contemporary art, artistic movements, and artists as case studies to study how ornamentation and patterning can form networks of resistance by foregrounding visual pleasure and by underscoring healing and joy as ways to be in the world. There will be 2 guest lectures from artists, curators, and/or art historians and weekly readings. Artists to be discussed include Chris Ofili, Raqib Shaw, Guadalupe Maravilla, Mickalene Thomas, Saya Woolfalk, Devan Shimoyama, Nick Cave, Xenobia Bailey, Joyce Kozloff, Judy Chicago, Barbara Chase-Riboud, Valerie Jaudon, Miriam Schapiro, El Anatsui, Monir, and many others.

60-398 Critical Studies: Social History of Animation

Intermittent: 9 units
Social History of Animation will investigate the history of animation from early experiments with trick film through the development of major studios, to independent animation, web based work and emerging forms. Animation will be analyzed and discussed in relation to the social movements and technological innovations that affected animators and their work. This class will read related texts and view examples from around the world to explore animation as a means for personal expression and as a reflection of the context in which they were made.

60-399 Art History/Theory Independent Study

Fall and Spring: 9 units
A tutorial course in which an Art student works individually on a self-generated project under the supervision of a School of Art faculty member. Prior to enrolling in Independent Study, the student must complete an "Independent Study Proposal" form (available in the bins on the 3rd floor of CFA) which is signed by the faculty member and the Assistant Head of the School of Art. Prerequisite: Art junior or senior status, or by instructor permission.

60-400 Senior Review

Spring
Students present their work and their ideas about their work to a faculty committee. This review affords graduating students the opportunity to analyze and summarize their work, and to engage a faculty committee in discussion about issues that face an artist preparing to enter a career in art. Although this is a non-credit course, it is required of all Art (BFA, BHA, BSA and BCSA) seniors.

60-401 Senior Studio

Fall: 10 units
The primary goal of Senior Studio is to create a context for students to develop and realize an ambitious and self-defined creative project. With the guidance of faculty, each student will pursue their own artistic goals and develop their ability to sustain focused artistic activity while developing their own voice. Additionally, Senior Studio will help students to: Foster a community and shared sense of purpose in an atmosphere of mutual support, critical dialog, knowledge exchange and camaraderie; Cultivate and apply professional practice skills by preparing for life after graduation; Participate in studio visits with a multidisciplinary team of faculty, visiting artists and critics; Collaboratively produce a successful Open Studio event on the last day of the semester.

60-402 Senior Studio

Spring: 10 units
Students continue a comprehensive two-semester capstone project. Each student pursues an ambitious and cohesive body of work with guidance by a team of School of Art faculty. Multimedia, multidisciplinary, and collaborative work is encouraged. Studio work is supplemented by group critiques, workshops on writing, professional presentation skills, career preparation, and technical instruction as needed.

60-403 Senior Critique Seminar

Fall and Spring: 10 units
Senior Critique Seminar comprised of group discussions that analyze the conceptual and aesthetic frameworks that surround each student's individual studio practice. The course supports independent inquiry, mature studio practice and both an in-depth critical reading of visual art and an increased comfort in the articulation of ideas and processes. Each student can expect two or more hour-long critiques throughout the semester, paired with ample time for individual studio work. These course discussions will also be informed by the Visiting Artist Lecture series and concepts and concerns carried from studio and academic seminar classes.

60-406 Advanced ETB: Internet Resistance

Intermittent: 10 units
Through booms and crashes, colonizations and disruptions, IPOs and LOLZ, Internet has been a spectacular laboratory of social conflict. But what can artists do on the net beside tweaking their pitiful portfolios and sinking into social media malaise? What is the function of the network in the age of pervasive surveillance, fake news, and filter bubbles? How to Internet under the First Troll President of the United States? Internet Resistance is both a schizo-seminar about critical issues in cyberculture and a trans-media studio to develop terrible ideas for the networked society. http://internetresistance.molleindustria.org/
Prerequisites: 60-110 or 60-210

60-407 IDeATe: Experimental Sound Synthesis

Spring: 9 units
This is a course that will guide students into the world of experimental approaches to music and sound production, with particular emphasis in some of the key practices and concepts developed in the 20th and 21st centuries. We will examine a variety of ways in which sound works are made and perceived; understanding the historical perspectives and critical viewpoints of each approach through the application of hands-on practicum. The topics covered in the course are divided into three large areas: the art of sound, the use of technology in the production of sound works, and the creation of interdisciplinary sound installation. Students from different disciplines will work together to collaborate on the designing, prototyping and execution of a series of ambitious projects in response to the topics covered in class.

Course Website: https://courses.ideate.cmu.edu/57-344 (https://courses.ideate.cmu.edu/57-344/)

60-408 Advanced ETB: Expanded Cinema

Intermittent: 10 units
Expanded Cinema is an innovative course that redefines the traditional boundaries of cinematic expression. Through hands-on experimentation with real-time analog and digital audiovisual systems, students will create multimedia performances, live cinema and immersive nightlife experiences. Through a combination of theoretical inquiry, practical experimentation, and creative production, students will interrogate and expand the possibilities of cinematic experience. Collaboration lies at the heart of expanded cinema, often involving interdisciplinary partnerships between filmmakers, visual artists, musicians, performers and technologists. In this course, students will have the opportunity to collaborate with their peers from diverse backgrounds, fostering a spirit of experimentation, dialogue and collective exploration. Tools and techniques students will work with include hardware video switchers, multi-camera production, video synthesis, projection mapping, real-time compositing and special effects, experimental sound and music, Hydra, Cables GL, Touch Designer and more.
Prerequisite: 60-110

60-410 Advanced ETB: Moving Image Magic: Visual Effects and Motion Graphics

Intermittent: 10 units
Fly like Harry Potter, fall into Alice's looking glass, create new worlds, or take a head-trip into the inner reaches of your subconscious. It's all possible in Moving Image Magic! This course serves as an introduction to the creation of extraordinary cinematic visions using a variety of analog and digital tools and techniques. These include: digital compositing, miniatures, motion tracking, rotoscoping, matte painting, puppets and motion graphics. Primary software tools are After Effects and Photoshop with forays into, Motion, Resolve, Logic and Smoke. Prerequisites: Electronic Media Studio: Introduction to the Moving Image or instructor permission.
Prerequisite: 60-110

60-412 Interactive Art and Computational Design

Intermittent: 12 units
This is an advanced studio course in arts-engineering and new media practice, with a special emphasis for Spring 2016 on mapping and information visualization using geographic data. Topics surveyed in the course will be tailored to student interests, and may include: experimental interface design, locative and mobile media, data-driven activism, image processing and computer vision-based interactions, and other topics. Through a small number of exploratory assignments and a public capstone project, students will bolster interdisciplinary problem-solving abilities and explore computation as a medium for curiosity-driven experimentation. Enrolling students are expected to have demonstrable programming skills, without exception, beyond the level of an introductory class such as 15-112. Although the course will provide technical overviews of major visualization toolkits (including D3, Processing, and openFrameworks), assignments may be executed in the student's preferred programming environment. Graduate students should register for section 51-882, 60-712, or 62-726, which meets with the undergraduate sections 60-412 and 51-482.
Prerequisites: 15-110 or 60-112 or 15-112

60-413 Advanced ETB: Real-Time Animation

Intermittent: 10 units
An exploratory studio that considers improvisational strategies for making animation within real-time computer graphics frameworks. Advancements in virtual production, real-time computer graphics engines, and visual programming tools for AV synthesis provide open frameworks for the exploration of animation in spatial and interactive contexts. Studio work will explore real-time animation in a variety of contexts, including screen-based interaction, site-specific installation, and spatial immersion. Conceptual frameworks drawn from the histories of animation, video art and Expanded Cinema, and immersive media design will inform collaborative group work and class discussion. Students without the prerequisite may register by instructor permission.
Prerequisites: 60-110 or 60-210

60-414 Advanced ETB: Animation Art and Technology

Spring: 12 units
Animation, Art, and Technology is an interdisciplinary, Art and Computer Science, cross-listed course. Faculty and teaching assistants from computer science and art teach the class as a team. It is a project-based course in which interdisciplinary teams of students can produce animations across platforms from single channel to augmented reality. Most of the animations have a substantive technical component and the students are challenged to consider innovation with content to be equal with the technical. The class includes basic tutorials for work in Maya and Unity leading toward more advanced applications and extensions of the software such as motion capture and algorithms for animating cloth, hair, particles, and immersive technologies.
Prerequisites: 60-333 Min. grade C or 60-220 Min. grade C or 60-110 Min. grade C or 60-125 Min. grade C

60-415 Advanced ETB: Animation Studio

Intermittent: 10 units
This is an open animation studio for students who want to improve existing animation skills and develop a personal animated short. The class will introduce a variety of techniques and concepts for animation production. Using both 2D and 3D tools, animation will be explored through short assignments designed to develop diverse skills and ideas. Each student will develop and produce a short animation. The class will engage in discussion and critique of each other's work along with examples of historic and contemporary animation.
Prerequisites: 60-125 Min. grade C or 60-220 Min. grade C or 60-333 Min. grade C or 60-110 Min. grade C

60-416 Advanced ETB: Documentary Storytelling

Intermittent: 10 units
In this class students will develop projects which use a variety of narrative concepts to convey stories in new ways. We will begin with a core practice around video, audio, and expand into internet media, performance, physical media and installation. Emphasis will be placed on story structure and strategies for choosing a media most appropriate to the narrative as well as the desired audience. Works by Janet Cardiff, Errol Morris, Spalding Gray, Werner Herzog, Laurie Anderson, This American Life and others will be mined for inspiration. With permission of instructor. We will also examine and discuss a range of historical and contemporary strategies employed by art makers who have used forums from on-line and virtual spaces to physical and site specific venues to expand and explore the relationship between the art object and the audience.
Prerequisite: 60-110

60-417 Advanced ETB: Video Art

Intermittent: 10 units
In this advanced studio course, students will focus on creating experimental works of video art exploring a variety of both historical and contemporary approaches to the field. Building from their prior foundational moving image courses, students will have the opportunity to dive deeply into an array of formal and conceptual approaches to the medium. Throughout the semester, students will produce several major assignments focused on the production of video artworks exploring visual effects and abstraction, documentary forms and video essays, performance-for-video, generative video, and multichannel media installation. Each assignment will be supported through relevant video and audio technical demonstrations. Additionally, all the major assignments will be supported by reading and screening homework, benchmark check-in assignments, workshops, visiting artist lectures, and in-progress meetings and amp; critiques. This class will give students the opportunity to independently explore their evolving material and conceptual interests within the language of video and allow students to develop their own research and fabrication strategies unique to their ideas with a supportive community operating in dialogue throughout the planning, making, and exhibiting process. The class will culminate in a public screening event at the end of the semester.
Prerequisite: 60-110

60-419 Advanced ETB: Experimental Game Studio: Digital Playgrounds

Intermittent: 10 units
A hands-on intermediate course focused on immersive environments, world building, and real time experiences pushing the boundaries of gaming. On a conceptual level we'll look at practices within digital art and independent game development: virtual architecture and sculpture, walking simulators, avatar-based performances, interactive art, procedural animation, environmental storytelling. On a technical level the course will introduce you to 3D modeling (Blender), game engine workflows and scripting (Unity) forming a scaffolding for advanced Electronic and Time-based courses.

Course Website: http://mycours.es/

60-422 Advanced ETB: Experimental Animation

Spring: 12 units
[IDeATe course] This class will examine animation production from the student's perspective. Animations that explore both form and content will be developed and discussed. Topics will include; non-linear narrative, visual music, puppetting, non-traditional materials, manipulation of motion and performance capture data and immersive environments.
Prerequisites: 60-110 or 60-220 or 60-333

60-425 Adv. ETB: (Im)Possible Worlds: 2D Animation, Motion Graphics and Visual Effects

Intermittent: 10 units
While developing proficiency in Adobe After Effects (and other tools) students will explore the experimental worldbuilding and storytelling possibilities of hybrid moving image media. This course is structured around technical tutorials and workshops, readings and screenings, the creation of collaborative and individual moving image projects, discussion and critique. Some of the themes we will explore include "The Fantastic" as expressed in the genres of horror, science fiction and fantasy. Artists whose work we will look to for inspiration include Jacolby Satterwhite, Shana Moulton, Rachel MacLean, Rachel Rose, Charles Atlas, Sondra Perry, Max Almy, Nam June Paik, Stan Van Der Beek, Zach Blas, Laurie Anderson, Cecile B. Evans, Ryan Trecartin, and many others.

60-428 Advanced ETB: Drawing with Machines

Intermittent: 12 units
This is an advanced studio course in experimental drawing, generative art, computational design, and mechatronic mishegas. Working at the boundaries of code, automation, physical materials, and gestural mark-making, we will explore personal and peculiar new approaches to digital fabrication; the development of ultra-niche workflows as a mode of creative practice; and the use of algorithms and machine collaborators as nontraditional intermediaries between mind, hand, and paper. Units in this course include: rule-based art and conditional design; chance and stochastic composition; real-time interaction and contingency; asemic cartography; synthetic automatism and ersatz perception; and more. Through rigorous exercises in freestyle computing, participants will develop skills in the control of machines by (e.g.) AxiDraw, Line-Us, Scribit, Rotrics, and Universal Robots to govern line, texture, tone, shape and mass in a variety of wet and dry drawing media. Interested students should have a portfolio of creative visual work, and programming experience equivalent to an introductory course such as 15-104, '110 or '112. Enrollment by permission of instructor.

60-429 Advanced CP/ETB: Digital Worlds: Making and Performing in Digital Contexts

Intermittent: 10 units
In this class students will look at digital spaces including social media, chatrooms, online galleries, phone applications, YouTube, 3D renderings, massively multi player online games, and more to produce works that respond to the specificity of these terrains. There is a rich history of site specificity and contextual practice in the physical world; this class will consider parallels in computer-based environments. In addition to theory and research components, students will develop a variety of technological skills in video production, webcasting, audio editing, gif animation, 3D modeling, and more in this course.
Prerequisite: 60-110

60-430 Advanced SIS: Open Sculpture

Intermittent: 10 units
This is a project-based studio class that allows for student-driven development of an artistic practice in 3D media, installation, site specific work, and systems. Ours is a widely inclusive and experimental definition of "sculpture." Aspects of making such as scale, medium, materials, methods, processes, and concept are unconstrained in projects assigned, while time and site become the more specific lens through which artistic peers may engage in group dialogue over common constraints. Through lectures, readings, discussion, individual meetings, hands-on-making, and group critiques, students will develop their abilities to brainstorm, make proposals, and turn ideas into action. Artists will build 3 to 4 major projects from start to finish, develop a working artist's statement and bibliography, and hone their individual sense of creative identity through the development of personal research interests, aesthetic sensibilities, and their own critical language surrounding common themes through their projects. An emphasis will be placed on extremely contemporary art, and students will make frequent presentations on new art works relevant to class discussions, as we develop our own class database of sculptors, fabricators, media artists, installation artists, makers, and thinkers. The concepts we will explore as a group include physical and sensorial properties such as scale, weight, balance, materiality, and connectivity; relationship of form to context and site; function, transformation, translation, iteration, and interactivity; and the continued relevancy of hand-making and physical construction in an era of post-industrial post-internet capitalism.

60-431 Advanced SIS: Installation

Intermittent: 10 units
This course explores a broad range of sculptural issues concerning the practice of Installation Art. This Studio course will primarily emphasize immersive environments (but not necessarily), given the circumstances of remote learning and one's bedroom as studio, or a similar venue, small and intimate may be more appropriate. Students expected to involve an ensemble of elements: objects, (found, purchased, reused, appropriated), made from an array of any kind of materials including natural materials; combined with time-based media; video, audio, performance, light etc. to create relationships within a particular space possibly as a 'site specific' venue in order to immerse the viewer within. Consider the notion of an immersive stage set, and the importance of documentation, 'Fabricated To Be Photographed, Video graphed, Digitally Imaged and/or Performed In.' Emphasis is on research about "place" and the proposal process for a specific context. Various artists, strategies, methods and materials will be investigated through projects, readings, lectures, visiting artists and discussions. Exercises and gestures are assigned initially, then students are expected to propose and establish their own projects/practice later in the semester.

60-433 Advanced SIS: Ceramics

Intermittent: 10 units
In this class, advanced ceramic students will investigate clay as an art material for personal expression. Students will build on their technical skills using materials and processes appropriate to their concepts while developing aesthetic sensibilities using historic and contemporary references in ceramics and other arts. Each student has the option to direct their own projects with guidance by the instructor upon demonstrating a complete understanding of the various construction skills and surface treatment techniques used in the medium. Students are expected to learn how to organize their projects and practice time management to generate and complete projects within the given time. Course work supports the development of a body of work to be used as a professional portfolio. Students are required to participate in critiques that analyze their own work and that of other artists and class participants to identify strengths and weaknesses in research and promote the growth and exchange of ideas. This class will consist of demonstrations and lectures as appropriate, research/writing assignments in and out of class, as well as work time. Students are required to develop a body of work within the context of the projects to express their individual voice.

60-435 SIS: Metals

Intermittent: 10 units
Studio focus on fabrication using light metalworking techniques including forming, joining, and finishing. Metalsmithing and jewelry techniques will be explored in the context of sculptural issues. Metal stretching, forging, brazing, texturing, small scale casting and coloring are also presented. Slides looking at small scale metalwork, as well contemporary sculpture using metal techniques will be presented periodically. Metals provided include copper ,brass, and bronze sheet and wire. Materials fee will also cover silver solder and other expendables. This is a repeatable class that will add to the tools and techniques acquired in earlier metals classes while expanding individual growth within the concept and context of sculpture.

60-437 Advanced CP/SIS: Environmental Sculpture

Intermittent: 10 units
Studio focus on sculpting with the environment. Includes object making, installations and site work with an emphasis on ecological themes: eco-material use and reuse, growing systems, environmental impact and a variety of other related issues. The semester is structured with initial exercises and a series of small gestures that lead to a major project. Students are required to explore and to develop proposal making skills in order to implement a site-specific project; either real or virtual. Students to produce a project complete with a well-documented outcome to include: visual representation, research and written descriptions.

60-440 Advanced SIS: Sculpture After the Internet

Intermittent: 10 units
Hito Steyerl asked, "Is the internet dead? ...[it is] completely surveilled, monopolized, and sanitized by common sense, copyright, control, and conformism... what happened to the internet after it stopped being a possibility?" This course assumes it is the artist's role to find and create possibilities in all contexts, and investigates what it means to create new possibilities by making physical objects, experiences, sculptures, installations, and systems in an era post-internet. As a project-based experimental lab, this class asks students to navigate back and forth between digital and physical creative tool sets to create new works. We will take inspiration from the history, theory, ideologies and technologies surrounding the internet, as well as from artists, animators, and engineers working on and around the internet today. We will explore issues surrounding automation, digital fabrication, and online maker / fabricator culture as tools to be used, but also as socio-political forces. Other concepts we will explore as a group include the relationship between body and technology; cybernetics, robotics, AI, and the uncanny valley; the relevancy of hand-making and physical construction post-automation; "image-objects;" scripted spaces; the producer-consumer continuum; the divisiveness and productiveness of online subcultures; anonymity; accessibility of information and production tools; and the spatial and temporal effects of inhabiting both digital and physical worlds. If we understand our current epoch as an era dominated by onscreen and networked experiences, this course investigates what it means to embrace, explore, explode, celebrate, negate, critique, reverse, or oppose that through the making of sculpture, broadly defined. This course assumes knowledge of at least very basic 3d modeling, and/or physical computing, and/or coding, and/or 3d media fabrication/construction techniques.
Prerequisites: 60-131 or 60-130 or 60-212 or 60-210 or 60-134 or 60-133 or 60-132

60-443 Adv. SIS: Special Topic

Intermittent: 10 units
In this course, students will learn both synthetic and natural dyeing techniques from dye painting, to mordant printing, to eco printing batik, tie-and-dye, indigo dyeing and more. Through readings, we will also explore the human quest for color throughout time - from the exploitation of flora and fauna to profiteering journeys across seas. The aim of this course is to introduce students to a variety of methods of dyeing that they may choose to incorporate into their current or future work, and leave with a new eye toward the origins, importance, and cultural significance of color.

60-446 Advanced SIS: Expanded Theater Fusion Studio

Intermittent: 10 units
[IDeATe collaborative course] As the boundaries between theater, art, entertainment and everyday life continue to expand through engagement with new technologies, it is critical that emerging artists and technologists be provided with the tools, language, and vision to thrive in the new millennium. Expanded Theater will reanimate classical modes of performance with media, networks, robotics, locative applications, and mobile systems. Considering theater as an ancient technology of mass participation and social cohesion, this fusion studio explores how emerging technologies can expand upon the basic theatrical relationships in new and culturally relevant ways. Collaboration and integration of design, media and storytelling is critical to this approach. Experimentation with new forms can reanimate the basic values of theater; the essential nature of a live event, the possibility of visionary spectacle, and the creation of meaning in dialogue with an audience. Expanded Theater is an opportunity to explore avenues outside of traditional theatrical production modes and beyond each student's individual discipline. The curriculum combines resources from Carnegie Mellon's Schools of Art and Drama, Integrative Design, Arts, and Technology (IDeATe), the Emerging Media Masters (EM2), Computer Science, the Robotics Institute, and their collaborators across the university in a new configuration. Expanded Theater will explore domains ranging from site specific and networked-based performance and interventionist practices, to pervasive social media technologies and their influence on interpersonal communication. The goal is to investigate contemporary languages that allow authors, actors and technologists to collaborate in ways that push beyond our present understanding of theatrical production and reception. This course alternates between two modes of research and design.

60-447 Advanced CP: Art at the End of the World

Intermittent: 10 units
The world is awash today in stories that anticipate an end to the world as we know it. These daunting narratives often anticipate techno-apocalypse, global pandemics, runaway climate change and mass extinctions. Their scale can appear to dwarf the actions of individual humans, and yet this is exactly where the work of the artist is proportionally most significant. Artists write the myths that help us understand the present, and create the monuments that explain the present to the future. They sound the alarm anew when sympathetic ears have grown deaf, and most importantly, they invent hopeful futures that were previously beyond imagination. Students in this course will learn significant historical and contemporary "end times" narratives, both utopian and dystopian, as well as the cultural responses to them. We will be using these as launching points for creatively engaging with our present apocalyptic predicaments. Students will visit regional locations that provide real-world grounding for these stories. They will use joy, introspection, humor, and courage, to create works using the full range of artistic expression from the highly ephemeral to the timeless. This course may never be offered again.

60-450 Advanced DP3: Drawing

Intermittent: 10 units
Figurative art retains aspects of the 'real' world as its subject matter. It has recognizable forms; it shapes, makes likenesses, and represents. Typically, 2D figurative work creates illusionistic depth to create spaces in which narratives occur and are portrayed. Within this realm, our course is unrestrained. All of our observations are valid, stories equal, feelings freed, fears unleashed and proclamations promoted. Projects across painting and drawing are drawn from both perception and invention and include working from the live model. The class will consist of studio time, critique, readings, discussion and museum/gallery visits.
Prerequisites: 60-160 or 60-157 or 60-150

60-451 Advanced DP3: Figurative Drawing

Intermittent: 10 units
This advanced course delves deeply into the artistic representation of the human body, drawing on art historical references to contextualize our relationship with the human form. Through intensive study and practice, students will develop a nuanced understanding of how artists throughout history have interpreted the body, and how these interpretations have shaped cultural and societal perspectives. Emphasis will be placed on refining our "looking" skills, honing our ability to observe and interpret the human figure with precision and sensitivity. Students will explore a variety of techniques and approaches to figure drawing, with the goal of developing a personal style and expressive voice. Central to the course is the question: What are we trying to say with our representations of the human body? Through critical analysis and thoughtful experimentation, students will explore this question, gaining a deeper understanding of the power and significance of figurative art.

60-452 Advanced DP3: Color

Intermittent: 10 units
In this advanced course, students will learn to employ a wide range of color theories and color systems through hands-on exercises and studies. Studies will be done primarily in paint, with some use of collage and digital media. These exercises will be aimed at mastering a variety of color approaches that will be applicable to each student's own artistic practice. Students will develop, based on their own interests, a cohesive body of work in which to practice and expand on the skills learned through the directed exercises. Studio work will be augmented by lectures, demonstrations, critiques, readings and critical discussion of writings about color.
Prerequisites: 60-160 or 60-157 or 60-150

Course Website: https://sites.google.com/andrew.cmu.edu/colorcourseclaytonmerrell/home (https://sites.google.com/andrew.cmu.edu/colorcourseclaytonmerrell/home/)

60-453 Advanced DP3: Painting

Fall and Spring: 10 units
This course is designed to help promote a painter's development, both conceptually and technically. It encourages students to expand their ideas through a diverse set of projects. Through research and studio experimentation, students will explore issues of scale, surface, materiality, process and performativity in painting. They will also consider notions of the "picturesque" and how non-artistic disciplines can inform painting. Lectures and assignments are designed to enrich the painter's conceptual and technical base and to promote creative growth.
Prerequisite: 60-250

60-454 Adv Studio: Small Things:Quiet interventions, Miniatures & the Power of Everyday

All Semesters: 10 units
This advanced studio class allows for the interdisciplinary exploration of historical, critical, craftbased, and conceptual issues surrounding the Small. The course will look at global and historical examples of small objects and the impulse for humans to make miniatures. It will consider site specific installations and interventions that are often not easily viewable. It is very easy for a large object, an expensive object, to make a big visual and/or social impact. What does it mean to work on a humble scale and with ephemeral and/or accessible materials? How does working small allow for generosity, play and adaptability? This is an interdisciplinary advanced studio course. Students will predominantly work in their own studios and bring their own practice/techniques and research to our conversation.

60-460 Advanced DP3: Paint/Print

Intermittent: 10 units
Paint/Print encourages creative exploration of the boundaries between print media and painting through material investigation, thereby eliminating any assumed hierarchy between the two modes of working. Painting and printmaking are open to the use of traditional and extreme image making methods including observational and fictional representations, abstraction, collage, installation, digital drawing/painting or other conceptual premises relevant to the successful presentation of privately held concerns in image-making. Emphasis will be on experimentation with both material and image. The class will consist of studio time, critique, readings, and discussion.
Prerequisites: 60-250 and 60-251

60-461 Advanced ETB: Experimental Capture

Intermittent: 12 units
This is an interdisciplinary studio course in expanded media practices that arise from using devices and algorithms to "capture" the world. We will explore experimental workflows, ranging from no-tech and low-tech to emerging and state-of-the-art techniques, in order to capture, model, and share new representations of people, objects, places and events. Through self-directed research projects, students will develop systems to capture a wide variety of phenomena, and creatively share the media they collect. We will cover a wide range of techniques and artistic practices that incorporate immersive, panoramic, high-speed, multiscopic, and multispectral imaging; depth sensors and 3D scanners; motion capture systems for gestures of the face, body, hand, and eye; computer vision and machine learning techniques for detection, tracking, recognition and classification; and other unusual, forgotten, and nascent technologies for transducing the unseen, ephemeral, and otherwise undetectable.

60-462 Advanced DP3: Painting Matter & Substance

Intermittent: 10 units
This course will be a hands-on investigation of the material, tangible, and physical aspects of painting. Students will learn how to make and use various paints, supports and grounds including oil paint, egg tempera, encaustic, watercolor/gouache, distemper, casein and fresco (in addition to other materials based on student interest). The working properties of various additives to and combinations of these media will be examined and experimented with. Technical issues affecting longevity will be addressed and experimentation will be encouraged. Students will investigate the work of other artists with a forensic "How did they do that?" approach. The second half of the semester will be devoted to studio work focusing on the ways in which each student's personal vision can be embodied and expanded in one or more of the above media.
Prerequisites: 60-150 and 60-250

60-464 Advanced DP3: Expanding the Graphic Novel

Intermittent: 10 units
In this course, students will critically and creatively engage with the medium of comics to learn how to better communicate their ideas in this format as well as challenge its boundaries. A substantial portion of the course will focus on familiarizing students with the basics of storytelling in a sequential narrative format and creating opportunities for students to discover, hone and explore their own voice and style. In addition to creating new work, students will also explore the history of comics and the origins of the "modern" graphic novel. Students will also be exposed to both graphic and non-graphic artists whose works has challenged and redefined the genre. We will explore these artists in order to understand how our own work borrows from and draws upon a rich lineage. Students will also be expected to think beyond the commonly accepted notions of comics and to question the relevancy of their work in this medium. Finally, each student will produce a new body of work that will culminate in the production of a 4-5 "page" "sequential" narrative.

60-466 Advanced DP3: Publishing as Artistic Practice

Intermittent: 10 units
This course will look at the history of artist multiples from artist books and zines, mail and subscription based practices, and editioned objects. Students will be introduced to techniques in traditional bookbinding, zine making as well as design and layout an artist book for mass publication. Studio work will focus on materials and processes that can be found and done at home as well as designing projects that utilize print-on-demand product services. We will be looking at contemporary artist's multiples that exist over a wide range of media, from fine art prints, sculptural and digital editions, and even performance and participatory work conceptualized as a multiple. We will discuss the economy and business structure behind independent publishing, looking into contemporary artists who are running their own presses, an emergence of art book and zine fairs, and envisioning alternative distribution opportunities for our artworks.
Prerequisites: 60-258 or 60-251

60-468 Advanced DP3: Print Media - Sculpture, Installation Screen Intensive

Intermittent: 10 units
This advanced print media course is a screen-printing intensive that moves print out of editioned works on paper. Students will utilize the multiple to create immersive wall installations, participatory social sculpture, objects that act as interventions, and hand-printed yardage that can be used in soft sculpture and/or wearable forms. Students will challenge their screen-printing techniques and the scale and reach of their printed matter. Projects will concern the role of ornamental design within socio-political-cultural frameworks and the role of "hand-made" within exchange and gift economies. Projects will problematize artworks in relationship to the human body: as wearer, as laborer, and as consumer.

60-470 Advanced DP3: Painting The Unconscious

Intermittent: 10 units
This course explores the threshold between the seen and unseen using a broad range of painting styles, techniques, and materials to explore the unconscious mind. Drawing upon a range of spiritual and occult practices, including tarot, surrealist games, automatic drawing, and color meditations, this class offers students the opportunity to explore processes that unlock the imaginative potential of the unconscious and adapt them to painting. Through a series of readings, presentations, field trips, and critiques, the class will gain knowledge of the practices and histories behind the unconscious in art and learn how to harness 'chance' more intentionally into their painting practice. This is a studio-based course in which emphasis is placed on independent research and studio productivity. We will discuss artists like Hilma af Klint, Remedios Varo, Leonara Carrington, Wassily Kandinsky, Austin Osman Spare, Ithell Colquhoun, Elijah Burgher, Xul Solar, Ghulam Rasool Santosh, Jesse Bransford, Elizabeth Insognia, Hilma's Ghost, Myrlande Constant, and Betye Saar as well as artistic movements including Symbolism, Surrealism, Transcendental Painting Group, and Neo Tantra Painting.

60-471 Advanced DP3: Photography/Print Workshop

Intermittent: 10 units
In this course in Photography and Print, students will develop semester-long individual projects in contemporary photography, printmaking, artists' books and/or multiples. Students will work in photography and amp;/ or print media, with an invitation to use either studio-based processes (intaglio, lithography, screenprint, photography lab) or work with hand-printing, digital or nontraditional approaches (monotype, stamps, stencils, rubbings, relief, digital photography). This will culminate in a capstone book, supported by the School of Art. Readings, discussion, critique, and visiting artists will enhance our conversation and research. As a workshop, this course is for students who are ready to explore their work more deeply and create ambitious self-driven projects.

60-472 Advanced DP3: Mutable Landscape

Intermittent: 10 units
With camera in hand, students will explore, document and invent a sense of place in Pittsburgh. Informed by photographic history and landscape studies, students will develop their own portfolios of digital prints. As a CFA Interdisciplinary photography course, students will be encouraged to consider their photographs in the medium of their home department, and in some cases as a starting point for projects in other materials. No prerequisites.

60-474 Advanced DP3: Photobook

Intermittent: 10 units
In this course, we will create books that explore visual narrative, sequencing, and sculptural form through the medium of photography. Additionally, we will consider the roles of image and text as well as design, editing, printing and binding. Our work will be informed by the history photobooks and artists' books, including by Ed Ruscha, Sophie Calle, Andres Gonzalez, Tommy Kha and Rinko Kawauchi. Lectures and field trips to book collections will guide our work too.

60-475 Advanced DP3: Open Print

Intermittent: 10 units
This advanced Print Media course focuses on student-driven development of a studio practice focused on contemporary print, multiples and distributed art. In this class, individuals will continue to build on technical skills and concepts, and the interdisciplinary applications of both, through self-directed, individual approaches. This course is for advanced students of art, ready to focus on larger-scaled, conceptually and formally ambitious projects that are formed from long-term investigations.
Prerequisites: 60-473 or 60-475 or 60-474 or 60-476 or 60-468

60-476 Advanced DP3: Serigraphy (Screenprinting)

Intermittent: 10 units
This course is a comprehensive and intensive study of Serigraphy (screenprinting), one of the most versatile and contemporary of printmaking techniques. The course is focused upon the mastery of this process. Students will explore multiple methods of image making (from hand-drawn to digital imaging) and will be introduced to CMYK printing. The emphasis of this course is on artistic work on paper, but will also be exposed to the ways that screenprint can work across a wide range of different media: from 2D (paper, canvas, cloth) to 3D (book forms, sculpture, installations) and utilizing printed multiples in participatory and exchange based artworks.

60-478 Advanced DP3: Photography Stands Up

Intermittent: 10 units
The value of a photograph is most often centered on the work it takes to construct an image but the work of photography does not stop there - printing out an image may also be the first step in building something else entirely. Photography Stands Up will treat the photographic print as a necessity, explore the photographic print as an object and most importantly consider the photographic print as a starting point for creating a significant work. After the past year of remote learning this course has a clear goal of getting students out of their seats, off the computer and away from the screen. This course will demand that we be active with our bodies and driven both conceptually and materially with an emphasis on experimentation as we vacillate between both digital and analog methodologies. We will explore printed photographs as objects that we may bend, fold, scratch, weave, dye, reconfigure and incorporate into future photographs. This course will introduce students to non-traditional methods of working in the Black and White Darkroom and will require students to print their images out on a regular basis using both the darkroom and digital print facilities. We will also explore the vast resource of the shooting studio, which we will use collectively during in class workshops - focused on putting our theories into practice. Participation in this course will grant students access to a digital camera and tripod to use for the duration of the semester and this tool will be a key component to in class workshops.

60-487 Advanced CP: The Amateur

Intermittent: 10 units
If a contemporary artist can truly do and be anything, how come so much art looks the same? More and more contemporary artists are pushing beyond the conventional media and methods of the art world by strategically operating as "professional" amateurs. The term amateur reflects a voluntary motivation to create as a result of personal passion for a particular activity, regardless of expertise or authority. For the artist, embracing the role of the amateur allows for the use of any profession, institution, or social activity as a possible material within their creative practice. This includes artists who "perform" as amateur preachers, psychologists, geneticists, politicians, and exotic dancers; artists who create amateur institutions like sanitariums, circuses, hair salons, talk shows, and planetariums; and artists who collaborate with professional hypnotists, ornithologists, stunt coordinators, ventriloquists, and diplomats in order to manifest their work. Students in this class will work on self-defined projects that utilize the role of the amateur as a critical method for expanding the breath and reach of their art practice into new forms and venues. With faculty mentorship, each student will be responsible for developing their projects through independent research, apprenticeships, and collaborations with experts in fields relevant to their work. Workshops, lectures, and in class critique of ongoing work will look at contemporary trends related to amateurism in art practice, theory, and the world at large. This class is not about being an amateur artist, but about being a serious artist who uses amateurism as a tool. Thus the class is only open to students with ???

60-491 Advanced CP/ETB: Art AFTER The End Of The World

All Semesters: 10 units
Taught by Prof. Rich Pell (School of Art BSA Faculty Advisor and founder of the Center for PostNatural History). This course will take students on a deep dive into our mythological, scientific and artistic understanding of world-changing catastrophic events, from the earliest human stories up to the present moment. Film and writings, fiction and non-fiction will inform a critical conversation about the important role of artists in these times. Contemporary research in science and critical theory will inform the development of unique self-defined creative practices that embrace our most durable human qualities of joy, empathy, humor, and courage. Field-trips (virtual and/or RL) will fuel group discussion and the development of new artistic works open to any media.

60-493 Advanced CP: Out There - Post-Studio Practice

Intermittent: 10 units
Since the Dada movement began to erode the importance of institutional validation, artists have consciously chosen to operate outside of a studio context in a variety of ways. The eighties saw the emergence of movements and artist-run organizations intent on removing institutional barriers for art practice, enabling performance, civic engagement, social and political intervention, and myriad other approaches to feed the dialogues surrounding art and culture. This class will consider the philosophical, ideological, aesthetic, and political motivations, which influence such artists and organizations and will look at writers who have provided a corresponding critical framework. Students will engage in research and reading to develop their own project(s), using the class as a space for dialog and development, and the time outside of the class as the space for execution and manifestation.

60-497 Advanced Studio: Science Fiction

Intermittent: 10 units
"There is nothing new under the sun, but there are new suns." - Octavia E. Butler "As the industrialized world undergoes daily transformations through the application of techno science to every aspect of life, science fiction has become an essential mode of imagining the horizons of possibility." - Istvan Csicsery-Ronay In this course students explore science fiction as expressed across media including film, television, music, contemporary art, literature, comics and games. Students will work in the medium(s) of their choice using the tactics of science fiction to investigate themes and topics including but not limited to: Utopia/Dystopia, Robots and A.I., Extraterrestrial Life, Speculative Design, Afrofuturism, Genomics, Transhumanism, Indigenous Futures, Posthumanism, Ecology, Climate Change, Space Travel, Time Travel and Alternative Histories.

60-499 Studio Independent Study

Fall and Spring
A tutorial studio in which an Art student works individually on a self-generated project under the supervision of a School of Art faculty member. Prior to enrolling in Independent Study, the student must complete an "Independent Study Proposal" form (available in the bins on the 3rd floor of CFA) which is signed by the faculty member and the Assistant Head of Academic Affairs of the School of Art. Prerequisite: Art Junior/Senior status and by instructor permission.

60-590 Internship

All Semesters
Art Internships are open to all BFA, BHA, BSA and BCSA Art students. Internships may take place with appropriate individuals or organizations within or outside of Carnegie Mellon University. The requirements for an internship are in the School of Art Handbook (available at the School of Art website). Prior to being enrolled for an internship, students must complete an Internship Proposal Form, which defines the goals of the internship. This form must be signed by their site supervisor and approved by the Assistant Head of the School of Art. Forms are available in the bins on the 3rd floor of CFA. Junior and Senior Art majors only.

School of Design

Eric Anderson, Interim Head
Location: Margaret Morrison Carnegie Hall 110
design.cmu.edu (http://design.cmu.edu)

Design at Carnegie Mellon

Design is the thoughtful activity that humanizes our environment through visual communication and the shaping of products that help us in our daily lives. Whether in magazines and books, posters and exhibitions, video and film, human-computer interactions, or any of the myriad of everyday products such as furniture, consumer goods, vehicles, or medical equipment, designers play an important role in shaping the form and content of our experience.

Designers are concerned with aesthetics, but they are equally concerned with serving people. This requires more than skill in the fine arts. It also requires knowledge about the needs, desires, expectations, and capabilities of human beings. It requires skills of observation and interpretation that help us understand the people that we want to serve. More than this, however, designers must also understand the technological issues that stand behind effective products. They must understand the materials, tools, and production processes of the modern world. An education in design is an education for the mind as well as the eye and hand.

The undergraduate program enables students to develop specialized skills in the areas of Product (Industrial) Design, Communication (Graphic) Design and Design for Environments (design for physical and digital environments), while providing them with a solid foundation in design studies. Students study systems thinking; the ability to see and solve problems at multiple levels of scale, and situate their work within larger social and environmental contexts.

The over-arching theme of the curricula is *design for interactions*, which acknowledges that ‘ecologies’ of products and communications often come together within complex physical *and* digital environments. Coursework balances making and theory with the integration of new, emergent technologies. Students are encouraged to explore the scope of design as well as the responsibility and ethics involved in the design of interactions between people, the built world, and the environment.

The curriculum is one that provides students with the ability to customize their degree: they may choose to specialize in one of three areas offered (Products, Communications, Environments), but also have the option of combining any two, to create a unique, interdisciplinary design degree.

The undergraduate curriculum also introduces students to three important areas of design focus: design for service, design for social innovation and transition design. These represent both new and established design approaches to framing and solving problems. In their senior year, students bring their disciplinary specialty (communications, products or environments) to projects that are situated within the areas of design for service and/or design for social innovation.

The School offers a Bachelor of Design with tracks in Communications, Products, or Environments.

Communications

The ability to communicate and shape meaning is one of the most powerful and ubiquitous forms of design in today’s world. Students learn to design effective communications across a wide variety of media that *always* exist within complex webs of interactions between people, products, and environments. Areas of study include narrative and storytelling, information design, and a variety of analog and digital visualization techniques. Students develop the ability to identify specific audiences and communicate to them through effective visual, verbal and aural communications that educate, inform and delight.

They study the dynamic and ‘emergent’ characteristics of communications in a globally networked society where technologies and modes of individual and mass communication are constantly changing. Students learn systems thinking and engage in an iterative, multi-disciplinary and collaborative design process that involves research, observation, prototyping and rigorous evaluation. Students develop the ability to identify and communicate to specific audiences through effective visual and verbal communications that educate, inform, delight and invite participation.

Products

Students learn to design products and their interactions within the context of human needs and they develop a deep understanding of the ways in which products shape behavior. Our curriculum acknowledges that no product exists in isolation—it is *always* part of a larger system comprised of people, communications and environments. Within the context of design for service, products exist as ‘touchpoints’ in a service ecology. For this reason, students learn systems thinking and engage in an iterative, multi-disciplinary and collaborative design process that involves research, observation, modeling/prototyping and rigorous evaluation.

Students are introduced to current production and manufacturing processes as well as sustainable approaches, such as cradle-to-cradle, lifecycle analysis and the use of new, more environmentally friendly materials. The School has a well-equipped analog and digital prototyping facility where students work with traditional materials such as wood and metal and learn to design and prototype using CAD software and 3D digital printers.

Environments

Students learn to design for complex environments that exist in the digital, physical and multi-modal realms. Most of the products and communications we interact with are situated within complex physical spaces (our homes, classrooms, places of business, shopping malls, even amusement parks). We also interact with complex online environments such as large websites, social networking and virtual reality environments. And increasingly we interact in ‘smart’ physical spaces with multi-modal communications in a combination of the analog and the digital.

In our curriculum, environments are seen as integrated and dynamic systems that require the design of interactions at multiple levels of scale. Students acquire a diverse set of skills that includes a deep understanding of spatial relationships, designing *with* and *for* emerging, multi-media technologies and an understanding of the cognitive challenges presented by multi-modal spaces.

Students who focus on the design of environments delve deep into systems thinking and systems dynamics and spend time learning to collaborate and lead within multi-disciplinary teams (solving large problems involving complex spaces almost always involves teams of people from different disciplines).

Design Minor Program

The School also offers a minor in Design for well-qualified students. Further information on the minor program is provided here (https://design.cmu.edu/about-our-programs/undergraduate-degrees/minor-design/).

The Design Curriculum

Minimum units required for Bachelor of Design	360

The design curriculum is for students who are interested in full-time undergraduate study leading to entry-level professional employment or advanced graduate study in the areas of Communication Design, Product Design, or Design for Environments. The first year is a period of discovery, where students explore studio projects and supporting courses in the ideas and methods of design practice as well as courses in design studies. The second and third years are a period of concentration and development primarily within the student's area(s) of specialization. The fourth year is a period of integration and advanced study, with studio projects involving teams of students from all areas of design. There are studio courses throughout all four years, supported by departmental electives in the ideas and methods of design practice and other courses in the history, theory, and criticism of design. In addition, the School also requires all students to take a substantial number of general education courses offered by other departments throughout the university. General education is an essential part of the education of a professional designer.

Foundation Year

In their first year, students are introduced to all three areas of design specialty: Product (Industrial), Communication (Graphic) and digital and physical Environments. Here, they explore these unique and complementary areas of design and gain a wide range of skill sets such as systems thinking, iterative process, collaboration and visualization, and work in both two and three dimensional materials as well as digital media.

At the end of their first year, students are given the opportunity to begin to focus their interests in two of three design areas (products/communications/environments) and will eventually decide upon a single area of focus or a dual path of study.

This is the first-year curriculum for all design students.

First Year

Fall

Studio		Units
51-101	Studio: Survey of Design	10
		10

Ideas and Methods		Units
51-121	Visualizing	10
		10

Design Studies		Units
51-175	Design Studies: Place	5
51-177	Design Studies: Histories	5
		10

General Education		Units
76-101	Interpretation and Argument	9
85-102	Introduction to Psychology	9
or 85-211	Cognitive Psychology	
or 85-241	Social Psychology	
88-120	Reason, Passion and Cognition	9
99-101	Core@CMU	3
		30

Spring

Studio		Units
51-102	Design Lab	10
		10

Ideas and Methods		Units
51-122	Collaborative Visualizing	10
51-132	Introduction to Photo Design	10
		20

Design Studies		Units
51-176	Design Studies: Futures	5
51-178	Design Studies: Experience	5
		10

Humanities & Social Sciences	**Units**
One course in the Dietrich College of Humanities & Social Sciences	**9**

Second Year

Following the first-year program, students select two out of three areas of interest: Products[P], Communications[C], Environments[E]. In the fourth semester students select one of the two areas to study more deeply. Students investigate the relationships people form with designed artifacts and the roles that physical, visual, and digital forms play in our lives. They apply what they learn to the design of products, communications, and environments that facilitate interactions. Students are also required to take general education courses to gain a broad vision of many disciplines and fields of knowledge that are relevant to design.

Second Year

Fall

Studio		Units
51-225	Communications Studio I: Understanding Form & Context (Pick two)	4.5, 4.5
or 51-245	Products Studio I: Understanding Form & Context	
or 51-265	Environments Studio I: Understanding Form & Context	

Ideas and Methods		Units
51-227	Prototyping Lab I: Communications (Pick two corresponding labs)	4.5, 4.5
or 51-247	Prototyping Lab I: Products	
or 51-267	Prototyping Lab I: Environments	
51-221	Color for Communications, Products, Environments	9
or 51-229	Digital Photographic Imaging	
or 51-242	How Things Work: Mechanics and Electronics	

Design Studies		Units
51-277	Design Studies: Systems	5
51-279	Design Studies: Cultures	5
		10

General Education		Units
xx-xxx	Academic Elective	9
		9

Spring

Studio		Units
51-228	Communications Studio II: Designing Communications for Interactions	9
or 51-248	Products Studio II: Designing Products for Interactions	
or 51-268	Environments Studio II: Designing Environments for Interaction	
		9

Ideas and Methods		Units
51-239	Prototyping Lab II: Communications	9
or 51-249	Prototyping Lab II: Products	
or 51-269	Prototyping Lab II: Environments	
		9

Design Studies		Units
51-282	Design Studies: Persuasion	5
51-284	Design Studies: Power	5
		10

General Education		Units
xx-xxx	Academic Elective	9
xx-xxx	Free Elective	9
		18

Third Year

In the fifth and sixth semesters, students may choose to continue their fourth semester area of focus, or they may choose to study their second area of study from the third semester. Students study how design functions at various levels of scale and degrees of complexity situated in specific contexts. They design products, communications, and environments that function as cohesive systems that live within the built and social worlds.

Third Year

Fall

Studio		Units
51-323	Communications Studio III: Designing for Complex Communication Systems	10
or 51-343	Products Studio III: Designing for Complex Products Systems	
or 51-363	Environments Studio III: Designing for Complex Environment Systems	
		10

Ideas and Methods (Select two Design Electives)		Units
51-xxx	Design Elective	9
51-xxx	Design Elective	9
		18

General Education		Units
xx-xxx	Academic Elective	9
xx-xxx	Free Elective	9
		18

Spring

Studio		Units
51-330	Communications Studio IV: Designing Communications for Social Systems	10
or 51-350	Products Studio IV: Designing Products for Social Systems	
or 51-360	Environments Studio IV: Designing Environments for Social Systems	
		10

Ideas and Methods (Select two Design Electives)		Units
51-xxx	Design Elective	9
51-xxx	Design Elective	9

General Education		Units
xx-xxx	Academic Elective	9
xx-xxx	Free Elective	9
		18

Fourth Year

In the senior year, students work to identify their next steps in professional practice, entrepreneurship, or in academia. They apply their design skills and knowledge to client-based and/or self-defined projects that focus on the design of services or social innovation.

The fall semester features the Design Research Studio, a semester-long project where students work in teams applying skill and knowledge learned in Products, Communications, and/or Environments. In the spring the Capstone Project challenges students to work independently on a semester-long project, deepening their understanding of service or social innovation design principles.

Fourth Year

Fall

Studio		Units
51-481	Senior Design Studio	12
		12

Ideas and Methods (Select one Design Elective)		Units
51-xxx	Design Elective	9
		9

General Education		Units
xx-xxx	Academic Elective	9
xx-xxx	Free Elective	10
		19

Spring

Studio		Units
51-480	Design Capstone Project	12
		12

Ideas and Methods (Select one Design Elective)		Units
51-xxx	Design Elective	9
		9

General Education		Units
xx-xxx	Free Elective	15
		15

Other Requirements

General education courses should be selected from other departments throughout the university. Students are strongly advised to select a balanced set of general education electives-in addition to Interpretation and Argument, Humanities & Social Sciences Elective, and Introduction to Psychology - from three broad areas of study: arts and humanities, social and behavioral sciences, and natural sciences and engineering, including mathematics. While free electives may include studio courses in other departments, academic electives are non-studio (lecture) courses in other departments. Specific recommendations (and general requirements) for electives in all of these areas are available from advisors in the School of Design. The School places strong emphasis on the value of general education for personal growth as well as professional development. General education electives allow a student to obtain a minor in another department or program, such as business, human-computer interaction, IDEATE, engineering, professional and technical writing, or architecture.

Students may enroll for no more than 18 units of independent study courses, and no more than one independent study per semester. A minimum 3.0 GPA is required for independent study. Independent study is permitted only in the third and fourth years of the program. Proposals for independent study courses must be developed jointly by the student and a faculty advisor. Guidelines are available from the School.

A minimum GPA of 2.0 is required to maintain Professional Program status. Grades lower than “C” in required Design courses will result in academic probation, suspension, or drop from the School of Design.

Full-time students are required to enroll for a minimum of 36 units per semester, with 45 units required for expected degree progress (typically five courses per semester). The minimum number of units required for graduation in Design is 360.

Academic Standards

The design curriculum adheres closely to the fundamental professional entry-level standards established by the two leading national design organizations: the American Institute of Graphic Arts (AIGA) and the Industrial Designers Society of America (IDSA).

Applications

The School of Design accepts applications from students who are completing secondary education or who wish to transfer from within Carnegie Mellon University. The School also accepts applications from students who wish to transfer from other institutions. Students applying for the program are asked to submit a digital portfolio as evidence of design ability. This is considered in balance with evidence of academic ability, based on secondary school grades, SAT scores, class rank, and letters of recommendation. The School also accepts applications for the design minors program for a limited number of spaces. Details are available on the Design website.

Emeriti Faculty

JOSEPH M. BALLAY, Professor Emeritus – M.F.A., Carnegie Mellon University; Carnegie Mellon, 1970-2002–

DAN BOYARSKI, Professor Emeritus – M.F.A., Indiana University School for Design, Kunstgewerbeschule, Basel, Switzerland; Carnegie Mellon, 1982-2018–

CHARLEE MAE BRODSKY, Professor Emeritus – M.F.A., Yale University; Carnegie Mellon, 1978-2022–

THOMAS L. MERRIMAN, Teaching Professor Emeritus – B.F.A., Carnegie Mellon University; Carnegie Mellon, 1985-2020–

Faculty

ERIC ANDERSON, Professor & Interim Head – M.A., Ohio State University; Carnegie Mellon, 1998–

MARK BASKINGER, Professor – Ph.D, Royal Melbourne Institute of Technology; Carnegie Mellon, 2003–

JONATHAN CHAPMAN, Professor – Ph.D, University of Brighton; Carnegie Mellon, 2017–

WAYNE CHUNG, Professor – MID, University of the Arts; Carnegie Mellon, 2007–

DINA EL-ZANFALY, Assistant Professor – Ph.D, MIT; Carnegie Mellon, 2019–

KELSEY ELDER, Assistant Professor – M.F.A., Cranbrook Academy of Art; Carnegie Mellon, 2022–

BRUCE HANINGTON, Professor – M.E.Des., University of Calgary; Carnegie Mellon, 1998–

SUNKI HONG, Assistant Professor – M.F.A, Iowa State University; Carnegie Mellon, 2023–

KRISTIN HUGHES, Associate Professor – M.F.A., Virginia Commonwealth University; Carnegie Mellon, 2001–

TERRY IRWIN, Professor – M.S., Schumacher College; Carnegie Mellon, 2009–

HAEYOUNG KIM, Assistant Professor – M.Des, Harvard University Graduate School of Design; Carnegie Mellon, 2023–

MARK MENTZER, Professor – B.F.A., Carnegie Mellon University; Carnegie Mellon, 1975–

DAPHNE PETERS, Assistant Teaching Professor – M.Des., Elisava, Escola Superior de Disseny; Carnegie Mellon, 2017–

STACIE ROHRBACH, Professor – M.GD, North Carolina State University; Carnegie Mellon, 2003–

DANIEL ROSENBERG , Assistant Professor – Ph.D, Massachusetts Institute of Technology; Carnegie Mellon, 2021–

PETER SCUPELLI, Associate Professor – MDes & Ph.D, Carnegie Mellon; Carnegie Mellon, 2011–

STEPHEN J. STADELMEIER, Associate Professor – M.S., Cornell University; Carnegie Mellon, 1977–

ANDREW TWIGG, Associate Teaching Professor – B.A., Allegheny College; Carnegie Mellon, 2014–

DYLAN VITONE, Associate Professor – M.F.A., Massachusetts College of Art; Carnegie Mellon, 2004–

BRETT YASKO, Assistant Teaching Professor – B.A., The American University, Washington D.C.; Carnegie Mellon, 2019–

MATT ZYWICA, Associate Teaching Professor – B.F.A., University of Illinois; Carnegie Mellon, 2014–

Special Faculty

ASHLEY DEAL, Special Faculty – M.Des, Carnegie Mellon University; Carnegie Mellon, 2016–

GIDEON KOSSOFF, Special Faculty – Ph.D, University of Dundee, Scotland; Carnegie Mellon, 2017–

RAELYNN OLEARY, Special Faculty – M.Des, Carnegie Mellon University; Carnegie Mellon, 2016–

Courtesy Appointments

DARAGH BYRNE, Associate Teaching Professor – School of Architecture & the Integrated Innovation Institute,

JONATHAN CAGAN, George Tallman Ladd Professor of Mechanical Engineering – College of Engineering,

JODI FORLIZZI, Professor & Director – Human-Computer Interaction Institute,

STEFAN GRUBER, Associate Professor – School of Architecture,

SUGURU ISHIZAKI, Associate Professor of Rhetoric and Visual Design – Department of English,

DAVID S. KAUFER, Professor of English and Rhetoric – Department of English,

GOLAN LEVIN, Professor & Director of Frank Ratchye Studio for Creative Inquiry – School of Art,

PAUL PANGARO, Professor of Practice – Ph.D, Brunel University; Carnegie Mellon, 2022–

CAMERON TONKINWISE, Professor of Design Studies – University of Technology Sydney,

JOHN ZIMMERMAN, Associate Professor – Human-Computer Interaction Institute,

Adjuncts of Practice

VICTORIA CROWLEY, Independent Design Consultant

JOE DICEY, Letterpress Facilities Manager

KELSEY DUSENKA, Independent Design Consultant

ARTHI KRISHNASWAMI, RyeCatcher

HANNAH DU PLESSIS, Fit Associates

MARC RETTIG, Fit Associates

MYRNA ROSEN, Calligraphy Guild of Pittsburgh

Professional Affiliates

MATT BEALE, Principal, Daedalus Design

TIM CUNNINGHAM, Founder, Daedalus Design

CHERYL DAHLE, Founder, Flip Labs

School of Design Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

51-101 Studio: Survey of Design

Fall: 10 units
Students will conduct activities that will help them notice design in the world, investigate how it works, and describe their thinking about design, through photography, video capture, sketching, note-taking and modeling. They will work through projects in various ways as a means of 'testing-out' and reflecting on command design approaches. This course is for undergraduate design majors only.

51-102 Design Lab

Spring: 10 units
Introduce concepts and methods to familiarize students with a range of analog and digital modes of working across products, communications, and environments. Students will use desktop modeling and comping methods to familiarize them with a range of basic materials to build confidence in using and manipulating material to represent ideas. This course is for freshman Design majors only.
Prerequisite: 51-101

51-121 Visualizing

Fall: 10 units
This course introduces basic drawing and sketching techniques including figure-ground translation, 2 pt perspective construction, storyboarding for explanation, diagramming for clarification, field notation for recording through guided exercises, demonstrations, and short projects.

51-122 Collaborative Visualizing

Spring: 10 units
This course introduces frameworks of notational, exploratory and explanatory sketching using collaborative methods and exercises to cooperatively communicate design ideas. This course is for undergraduate design majors only.
Prerequisite: 51-121

51-132 Introduction to Photo Design

Spring: 10 units
Using a digital camera, students learn how to extend their 'seeing' with the camera, both in the world and in a shooting studio. Through shooting assignments student will understand how to: deconstruct image meaning and aesthetical choices, construction of photographic meaning and aesthetics, an understanding of color and how color delivers meaning, how a photographic studio works, proper digital photographic workflow and contemporary trends in photography. Intended for Design Majors, or permission of the instructor.
Prerequisite: 51-101

51-171 Placing

Fall: 10 units
This course will explore the context in which students study design. Using primarily photography, students compare where they are from to the bioregion of the Ohio Valley of Western Pennsylvania and the history of the steel town, Pittsburgh. Students also learn about the modern Western emergence of design as a profession and discipline, and map the edges of current design practice by interacting with local professionals.

51-172 Systems

Spring: 9 units
This course explores how to understand complex phenomena by creating models of interrelations between components. Students learn soft systems diagramming as well as the systems thinking associated with ecologies, integrative science and socio-technical regimes. Students also learn how to see design as a way of making interventions into leverage points in a system in order to transform its functions.

51-173 Human Experience in Design

Intermittent: 9 units
Design touches, and can profoundly affect, people's lives. But why? And how? This course begins with a broad definition of what design is (and can be). We'll see how design is about the process as much as it is about the final product. We'll look at how the end user interacts with what is designed. And we'll discuss how designers need to think beyond the actual artifact to what lies behind it. We'll touch on design theory, design practice, design responsibility and even some design history. And through a series of guest lectures, explorations of other designers' work, field trips, viewings, class discussions and projects, we'll try to determine just what design is and what designers do.

51-175 Design Studies: Place

Fall: 5 units
"Place" introduces you to place-based design thinking. It trains your senses to perceive all that is designed and sustains everyday human lifestyles, especially those infrastructures and services invisible to city dwellers in the built environment. In addition, you will recognize relations between natural and artificial worlds. Coursework covers methods to evaluate individual and collective environmental and social impact at a regional and local level through techniques that develop capacities to reveal dynamic relationships among elements.

51-176 Design Studies: Futures

Spring: 5 units
"Futures" frames design in a temporally-extended, systemic context. It offers essential perspectives, practices, and competencies that are increasingly called for as designers progress in their work and careers, and as the design field evolves to acknowledge its significant powers and responsibilities. You will explore numerous futures methods, which support designers through ideation and storytelling, problem-finding and framing, brief formulation, project coordination, and collaboration. Coursework includes engagement with readings and videos, hands-on creative workshops, and visual prototyping and sketching.

51-177 Design Studies: Histories

Fall: 5 units
Histories explores a plurality of design histories extending beyond the dominant, Anglo-European story of Design. Through a series of guest lectures, critical readings, and offsite explorations, you will expand your understanding of histories, which evolve and change over time in the context of broader social, technological, environmental, economic, and political developments. Coursework includes exploring, developing, and documenting diverse historical perspectives of a research interest of your choice. Final projects will culminate in a presentation of student work.

51-178 Design Studies: Experience

Spring: 5 units
Experience explores how design touches peoples lives, and shapes their materials and non-material worlds. Through a series of lectures, viewings, and class discussions, we'll try to determine just what design is and what designers can do. We will explore contrasting definitions of design, and get to know it as an experientially-rich process. Well examine how users and audiences interact with what is designed, and debate the designers responsibility to consider what lies behind it. Coursework includes individual and team projects exploring design's role in shaping our experience of the world.

51-208 Research Methods

Spring: 4.5 units
Learn how to select, conduct, and develop appropriate research methods for understanding and discovering contextual information and behaviors of human participants.

51-215 Making Short Films

Intermittent: 3 units
The objective of this course is to provide students with a practical, technical and theoretical foundation in video work. Students leaving this class will have gained knowledge of developing a moving picture from start to finish. Students will learn storyboard, plan, production, and post-production video. Equally importantly students will start to develop their own visual aesthetics in the creation of 1 short moving pictures. The primary software for this course is Adobe Photoshop, with which students will explore construction, combination, manipulation, input, and output of video as a means of narrative creation. This Micro course will run between 5-6 weeks. The instructor will fly into Doha for a short period of face-to-face classes, centered around a Saturday. Enrolled students should expect two 90-minute face-to-face classes during the week before or after this Saturday date, as well as four 90-minute evening (6-7:30 pm) video classes over the duration of the Micro course (typically two before the campus visit, and two after, although instructors can change this). Specific dates will be confirmed in the syllabus closer to fall semester.

51-221 Color for Communications, Products, Environments

Fall: 9 units
This course will explore the fundamentals of color through the implementation of various media as they apply to their use in communication and expression in design. While this course does not deal with color theory per se we will spend time on the causes and effects of color interaction, color contrasts, color harmonies and color strategies for the effective use of color in our visual design work. We will use both nature and man made constructs to discuss how color affects what we see and its effect on our visual world. Short exercises and longer- term projects will be the vehicles of our explorations. This course is for Sophomore Design Majors.
Prerequisite: 51-122

51-223 Color for Communications & Products

All Semesters: 9 units
This course will explore the fundamentals of color through the implementation of various media as they apply to their use in communication and expression in design. While this course does not deal with color theory per se we will spend time on the causes and effects of color interaction, color contrasts, color harmonies and color strategies for the effective use of color in our design work. We will use both nature and man made constructs to discuss how color affects what we see and its effect on our visual world. Short exercises and longer- term projects will be the vehicles of our explorations. This course is for Sophomore Design Majors.

51-225 Communications Studio I: Understanding Form & Context

Fall: 4.5 units
Giving form to messages and information using type, color, and images will be the focus of this introductory studio in Communication Design. Understanding the connection between content, intent, and form will be the goal of every project and exercise. Principles of hierarchy, chunking, sequence, clarity, and visual voice will guide work for the screen and the printed page, in dynamic and static forms.
Prerequisite: 51-122

51-227 Prototyping Lab I: Communications

Fall: 4.5 units
Learn the core methods and tools of visual communication design, with a focus on Adobe CC: particularly InDesign, Illustrator, Photoshop, Prototyping tools, and After Effects. The learning of software ideally will align with the activities conducted in the Communications Studio. This is a requirement for Design sophomores studying Communications.

51-228 Communications Studio II: Designing Communications for Interactions

Spring: 9 units
At its most basic level, Communication Design conveys ideas and translates concepts into visual form. This form needs to be such that an audience will want to look, engage and (hopefully) learn. To get there, you will need to develop your process. Your own unique path. This is not easily done. It's also not prescriptive. There isn't one defined straight path. It's more like a wild and crazy zig-zag. A goal of this course is for you to give yourself permission to wander beyond the areas you're comfortable withto not be afraid of stretching beyond where you think you may be capable. And to develop your own individual process. We will work on a series of four print-based and interactive projects. You will broaden your understanding of color, scale, hierarchy, typography, grid systems and how to make things that both communicate and resonate with your audience. Everything we design is an opportunity to make work that is compelling, memorable and moving. This is a required course for all SoD Sophomores who are pursuing the Communications track.
Prerequisite: 51-225

51-229 Digital Photographic Imaging

Fall: 9 units
The objective of this course is to provide students with a practical, technical and theoretical foundation in digital imaging. The primary software for this course is Adobe Photoshop, with which students will explore construction, combination, manipulation, input, and output of image as a means of narrative creation. Through project critique and other discussion, we will also consider the aesthetic and political implications of the emergence of this and other new electronic imaging technologies.

51-231 Calligraphy I

All Semesters: 9 units
Working with pure unadorned Roman letterforms, this course introduces students to the theory and practice of hand-generated letters, employing a variety of mark-making tools. This course provides an in-depth understanding of the basic principles and techniques of the art of formal writing. Rhythm, texture and composition are achieved through routine, elementary exercises using geometric forms, demanding concentration and manual discipline with the development of hand-eye coordination. The function, use, and harmonious sequencing of letterforms is taught through weekly projects. Awareness of rhythm, texture and letterform structure is achieved through routine exercises. Drills, demonstrations, discussions, individual and class critiques are on-going. Additional related topics and activities introduced in class include books: binding and design. A brief introduction to the historical development of our Western alphabet is provided through film, slides, demonstrations, with discussion of twentieth-century type designs. Students also gain exposure to letter vocabulary, paleography, monoprints, words and punctuation, classical page design, publication design-past and present, and calligraphy's role in design today. Thinking with hands and eyes, the manual placement and spacing of letters practiced in this course awakens sensitivity and judgment in the designer.

51-232 Calligraphy II

All Semesters: 9 units
This course serves as a continuation and deeper investigation of topics explored in Calligraphy I, where students tackle advanced problems in calligraphy and lettering. The introduction of new hands is to be decided by the student and instructor. Prerequisites: 51231
Prerequisite: 51-231

51-236 Information Design

Fall and Spring: 9 units
This studio course focuses on teaching a basic visual design process from ethnographic research through ideation to finished artifact. Students will work individually and in teams to gain proficiency in applying specific design techniques to information design challenges. Students will attend lectures to gain new perspectives, engage in projects to learn through making, conduct readings to balance theory and practice, participate in critiques to verbalize their views and consider alternate perspectives, join in discussions to develop shared understanding, give presentations to communicate their thinking, and complete tutorials and learn software for additional insight.

51-239 Prototyping Lab II: Communications

Spring: 9 units
Program simple websites as a means of learning basic HTML 5.0 and CSS; prepare documents for digital and print production using Adobe InDesign, Illustrator, Acrobat; learn basics of UX prototyping
Prerequisite: 51-227

51-240 Design, Brands, & Futures: Service Design Approaches and Pivots

Intermittent: 3 units
This micro will introduce students to service design and help students develop skillsets and knowledge that will serve them in their particular area of study. This includes ways of analyzing existing businesses and services, empathizing with multiple stakeholders in a complex system, and developing ideas for ways that existing businesses and services could adapt and evolve to emerge from the pandemic more resilient. Students will also use the power of storytelling to develop presentations that communicate their ideas in compelling ways.

51-241 How People Work

Fall: 9 units
51241 How People Work: Human Factors (ID/CD Lab I) This course is a general introduction to the field of human-centered design and applied human factors. It centers on the understanding of physical, cognitive, and emotional human needs and desires, including methods employed to acquire this information and translate it into useful criteria for the design and evaluation of products. Lecture, discussion, lab exercises, and projects are employed. Required of all sophomore design students. Others admitted by permission of instructor only.

51-242 How Things Work: Mechanics and Electronics

Intermittent: 9 units
This course investigates the basic principles of mechanics and electronics. Through the combination of lectures, investigations, and lab experiments, students develop simplified representations of complex systems. The skills of freehand drawing, mechanical drawing and three-dimensional models are employed and developed during the project sequence. Instructor permission required for non-Design majors.

51-245 Products Studio I: Understanding Form & Context

Fall: 4.5 units
This mini-semester course takes students through a progression of exercises and projects that investigate how object forms can relate to people through reasons of looks, feel, function, make, and preference. The understanding of context plays a role as the system of internal and external factors and conditions that cause people to interact a particular way through how they recognize, handle, move, and perform activity with the form and material of an object. Drawing and physical modeling become essential tools for the planning, development, and communication of these ideas.
Prerequisite: 51-102

51-247 Prototyping Lab I: Products

Fall: 4.5 units
The course will consist of introductions, demonstrations and solutions to introductory aspects of SolidWorks. Forming foundation skills in CAD-based communication and problem solving will be emphasized.

51-248 Products Studio II: Designing Products for Interactions

Spring: 9 units
This course provides essential methodologies for the conceiving, planning, and realization of three dimensional objects and is coordinated with the Prototyping Lab 2 course to provide for an experiential understanding of the relationship between designing and making. From an operational standpoint, this course gives primacy to the material object to probe its characteristics more deeply and to critically explore an object's role as part of the assemblage of interaction and experience. Students will develop three-dimensional visual literacy, emphasizing the relationship between form factors and overall visual/physical impact in service of supporting human interactions. Through a hands-on approach, this course covers the "how" and the "why" of product/object development through the primary lens of "design for interactions."
Prerequisite: 51-245

51-249 Prototyping Lab II: Products

Spring: 9 units
This course introduces students to high fidelity modeling techniques through a series of machines, processes, and or methods to simulate desired form, scale, and proportions.
Prerequisite: 51-247

51-251 Digital Prototyping

Fall: 4.5 units
A half-semester laboratory mini-course introducing 3D modeling software. Each class meeting consists of an introduction to and demonstration of specific aspects and functions of SolidWorks software. At the end of each class session, work related to the covered topic(s) will be assigned for completion by the next class meeting. This course is a requirement for all ID majors. Instructor permission required for non-ID majors.

51-252 Design, Brands, and Futures: Design Thinking for Sustainable Change

Intermittent: 3 units
Design Thinking is a powerful process that expands creative potential and drives sustainable innovation. Work with CMU Design faculty and acquire powerful creative tools that you can immediately put into practice as an agent of sustainable change.

51-256 Design, Brands, and Futures: Designing Product and Service Identities

Intermittent: 3 units
In this course, students and I will delve into investigating social and cultural patternsboth historical and contemporarywhich guide effective approaches to branding products and services. For example, what helps people feel happy, accomplished, confident? What do they wear? What do they eat? Where do they gather? What do they do for enjoyment? What do they value? Students will work to align their discoveries to the graphic forms, colors, typography, and taglines that they create as part of a comprehensive branding strategy, which they will base on a product or service of their own choosing. Students will achieve these goals by engaging in a creative process where they will sketch, iterate, test, and refine graphic symbols and typography using conventional paper and pencils as well as Adobe Illustrator. Throughout the course, we'll also discuss communication trends and the role technology plays in shaping how and where brands appear in our everyday lives. Based on what they learn, students will propose various forms that their graphic symbols may take and brainstorm contexts in which they may appear. For example, how might their concepts appear in motion in a video viewed on a phone, or on the side of a food truck? Through this process students will explore the affordances and limitations of various mediums and contexts and test the flexibility of the branding systems the create.

51-257 Introduction to Computing for Creative Practices

Intermittent: 10 units
This course is an introduction to Java programming for designers, architects, artists and other visual thinkers, using the popular "Processing" Java toolkit for interactive graphics. Intended for students with little or no prior programming experience, the course uses interaction and visualization as a gateway for learning the traditional programming constructs and the fundamental algorithms typically found in a first course in programming. Students will become familiar with essential programming concepts (types, variables, control, user input, arrays, files, and objects) through the development of interactive games, information visualizations, and computationally-generated forms. Because of limited space, only Design majors may take this course. Students following an IDEATE concentration or minor should register for 15-104.

51-261 Communication & Digital Design Fundamentals

Fall: 9 units
A one-semester course that introduces non-majors to the field of communication design. Through studio projects, lectures, and demonstrations, students become familiar with the visual and verbal language of communication designers, the design process, and the communicative value of word and image. Macintosh proficiency required. This course (or 51262) is required for Design minors.

51-262 Design Center: Communication and Digital Design Fundamentals

Spring: 9 units
A one-semester course that introduces non-majors to the field of communication design. Through studio projects, lectures, and demonstrations, students become familiar with the visual and verbal language of communication designers, the design process, and the communicative value of word and image. Macintosh proficiency required.

51-264 Product Design Fundamentals: Design for Interactions for Products

Spring: 9 units
In this one-semester studio-like course non-majors are introduced to product design from the product designer's point of view. Through studio projects, lectures, and discussions, students will learn approaches to defining and visualizing product concepts for mass production. Case histories and the analysis of existing products will supplement hands-on experience in developing product concepts. This course is required for all Design minors.

51-265 Environments Studio I: Understanding Form & Context

Fall: 4.5 units
This mini course will teach you the elemental strategies for designing meaningful, narrative-driven spaces and experiences. Through projects looking at the world as it is today and speculatively 10 years in the future, you will develop your ability to think through the relationship between time, space, scale, materials, and technology. You will use what you learn in 51-267 (Prototyping Lab 1: Environments) to develop both analog and digital high-fidelity artifacts that communicate the interactive experiences you have designed. This course is a requirement for Design students who wish to study Environments during their time at SoD.
Prerequisite: 51-102

51-267 Prototyping Lab I: Environments

Fall: 4.5 units
This mini course will provide you with practical skills to aid you in the design of interactions in environments and how to communicate your ideas to others. These include low-fi prototyping, rapid making, high-fidelity scale models, digital 3D modeling, typography in space, UI/UX strategies, augmented reality (AR) prototyping, basic electronic prototyping, and the development of concept videos. Building upon what was learned in your first year, you will continue to use Adobe Photoshop and Illustrator, while also being introduced to Adobe AfterEffects, Aero, and SketchUp. This course is a requirement for Design students who wish to study Environments during their time at SoD.
Prerequisite: 51-102

51-268 Environments Studio II: Designing Environments for Interaction

Spring: 9 units
Introduce students to the concept of resonant environments that provide meaningful physical and virtual experiences; utilize a range and combination of analog and digital tools for high fidelity output.
Prerequisite: 51-265

51-269 Prototyping Lab II: Environments

Spring: 9 units
Explore simple reactive and interactive programming as a means to support virtual and hybrid digital/physical environments.
Prerequisite: 51-267

51-271 How People Work

Fall: 9 units
Introduction to human-centered principles of design, including physical, cognitive, and emotional human factors. Capacities and limitations of people affected by design are learned through the study of known principles and user research. The course is delivered through a series of combined lectures, readings, hands-on lab activities, and a team project applying human-centered field research methods and design.

51-272 Cultures

Spring: 4.5 units
Explore the sociotechnical aspects of the many identity based differences between people. These differences may be not only cultural, but also related to gender, age, class, race etc. The course will survey critical theories that are useful for understanding how difference both constructs, and is constructed, by systems, practices and things. Students will also explore different frameworks and strategies for exploring questions of difference, and to think critically around the ethical and political implications for design interventions.

51-277 Design Studies: Systems

Fall: 5 units
"Systems" prepares you to design for, and within, complex systems. You will make use of systems theory and experiment with systems-thinking techniques to interpret and illustrate how ecological, social, and cultural systems operate at different levels of scale. You will also learn to identify leverage points within a system, and design ways to intervene that creates openings for norms, behaviors, attitudes, and habits. Coursework includes exposure to theoretical frameworks, analysis of case studies, and complexity mapping projects to analyze and represent the world from scalar and systemic perspectives.

51-279 Design Studies: Cultures

Fall: 5 units
"Cultures" immerses you in ways in which societies shape design, and how design shapes societies in return, rooted in historical and philosophical origins of identities and cultures. We will explore various aspects of human difference and relate them to the designed, material worlds we inhabit. Coursework involves reflective practices to connect theoretical, personal, and contextual understandings of the themes exposed, to explore meaning, purpose, and values that represent you as a person and as a designer.

51-282 Design Studies: Persuasion

Spring: 5 units
"Persuasion" develops your capacity to put across your message, to get other people to understand you, to value your work, and to want to work with youskills that will be central to your career, both inside and outside of design. Understanding what persuades you and othershow we are influenced by other people, by media, by technology, by our environment, by designis a critical skill to develop in better understanding yourself, your design practice, those around you, and society more widely. Coursework includes a series of persuasive, exploratory exercises including filmmaking and exhibition of speculative work.

51-284 Design Studies: Power

Spring: 5 units
"Power" explores the concepts of politics, the political, and the powers that intertwine with design. You will delve into the mesh conformed by plural forms of knowledge, wisdom, power, and designs. A deepening into matters of ideology allows us to think critically about how designed artifacts are the embodiment of ideology; having the power to influence what people think, and shape their aspirations, desires, and values. You will be exposed to emerging design practices and theories that harness the power of design for social change with sociocultural and ecological mindsets. Coursework includes facilitation of activities for the collective analysis of topics at the intersection of design and power.

51-317 Publication

Intermittent: 9 units
For this course you will arrive on Day 1 with a story that you want to tell. You will then spend the semester iterating, designing, producing, publishing and, finally, putting your publication out into the world in a compelling, memorable and designerly way. Your publication can take the form of a substantial book, a series of smaller booklets or zines, a film, an interactive experience, a piece of public art, a combination of two or more of these or something else entirely. As long as it can be disseminated beyond the classroom and campus. This course will only work for those who have an idea. You must come into this course with a firm grasp of the story you want to tell, how you want to tell it and who you want to tell it to. There is only one project for this course. It will be robust and multi-faceted and you will only have 13 weeks to make it. So you need to be ready to go from the start. The first class will be dedicated to hearing your pitch for what you want to do. It will then be determined if you should stay on the roster.

51-318 Design Center:Community Rituals & Civic Ceremony: Building immersive experiences

Intermittent: 4.5 units
This course combines social games and physical techniques from public theatre with contemporary design practices in the immersive experience industry to examine group rituals and civic ceremonies from ancient Mesopotamian, Mesoamerican, and Asian traditions. Participants will create and perform original civic ceremonies that harness group energy to "enchant" their surroundings, their belongings, and each other.

51-319 Digital Photography in the Real World

Intermittent: 4.5 units
DIGITAL PHOTOGRAPHY IN THE REAL WORLD Photographers are active observers. They look until they see what they want others to see -then they compose and click the shutter. In this course students will walk streets with their cameras. They will learn how to use their cameras to better understand what they believe is important, beautiful, and/or intriguing in the world. They will also learn how to communicate their imagery to others through screen-based and print output. Assignments range from accurately describing reality, to showing aspects of life that should be improved, to making images for purely aesthetic reasons. There are two main goals to this course: learning the fundamentals of operating a digital camera and producing digital output; and, learning to become better 'seers' in the world. Students must own a camera but no prior photographic experience is necessary.

51-321 Design Center: Photographic Narrative

Intermittent: 9 units
Most photographs tell stories. We see photographs in newspapers, magazines, snapshot albums, on the web, in books, and in posters. In these contexts photographs often work with words to convey meaning, whether they are shown with captions, news stories, or just with titles. Photographs can work without words, too, to create purely visual narratives. In this course, students will make a photo narrative and determine how it will be seen. Students may make photo books, for example, or decide that their images will be seen digitally on screen. While students are making photographs, we will explore the rich traditions of photographic story-telling that range from the world-oriented work of photo-journalist W. Eugene Smith to the documentarians such as Walker Evans, Nicholas Nixon, and Alec Soth. We will look at photographers, too, who construct fictional worlds, such as Duane Michals, Cindy Sherman, and Gregory Crewdson. As students make their own narratives, we will look at the interplay between words and photographic images; how images are paced and scaled to create rhythm; how photographs are sequenced to tell stories; and other formal elements involved in creating visual narratives. 12-15 students. Prerequisite-a college level photography course.

51-322 Advanced Digital Imaging

Intermittent: 4.5 units
Building on the technical skills and methods of communicating narrative learned in Digital Imaging Advanced Digital Imaging takes communication to the next level of resolution with particular concern in artifact creation. Students explore historical and groundbreaking means of content delivery.

51-323 Communications Studio III: Designing for Complex Communication Systems

Fall: 10 units
Gain a greater understanding of how to craft communications that resonate with specific people by researching topics/audiences/contexts, by developing/iterating/testing concepts, and by investigating deeply the nuances of typographic form/image/sequencing of interactions; learn how to craft graphic form to express ideas that are not dependent on the reading of words themselves; continue to develop communication systems
Prerequisites: 51-228 and 51-225

51-324 Basic 3D Prototyping

Spring: 4.5 units
A half-semester laboratory mini-course introducing a range of materials, methods, and workshop techniques by which designers prototype designs in three dimensions. Basic competence in shop techniques is established by bringing to realization a series of simple artifacts. Studio and model shop tools are required; lab fee. For Design students only.

51-326 Communication Systems Design for Social Equity

Intermittent: 9 units
This course will take a systems approach to understanding issues related to social equity and justice and will explore the creation of effective communication strategies for specific audiences across a range of analog and digital platforms. In this class students will explore and discuss the meaning of "social equity and justice" and explore its many facets through 1) assigned readings and discussions; 2) research on the problem and the stakeholders affected by it; 3) and the design of a communication system. A review of communication design from historic social equity movements will introduce the course. Students will work in teams to select a social justice issue, and map both the problem and the stakeholder groups affected by it in order to identify target audiences for the communication system. Over the course of the semester, students will formulate content and messaging for use in a range of communications that work together as a system such as brief tweets and messages + images for online platforms, concepts for apps, brief videos as well as print applications such as posters, brochures etc. The final result will be a multi-pronged campaign to raise awareness and motivate action with respect to a social justice/equity problem. Class will meet once a week for 2 hours and 50 minutes. Students will be asked to work in Miro and other online collaborative platforms. This course will be offered remotely.

51-327 Design Center: Introduction to Web Design

Fall: 9 units
This class will introduce the basics of designing and building websites, the fundamentals of HTML5 and CSS3, and responsive design approaches to assist students in creating semantically sound web pages that can be viewed across a variety of platforms, devices and browsers. The class will help students understand the constraints and advantages of working with the web, with this course focused on technically pragmatic solutions for making websites. Students will also be exposed to content management systems and topics such as responsive web design, research, and information architecture. Upon completion, students will be capable of designing, creating, launching and managing their own web sites. Your own laptop is required, with the following software installed: Adobe CS6 or later, as well as other open-sourced software. This course is for Design Majors only, or by special permission of the instructor.

51-328 Design Center: Design for Digital Systems

Intermittent: 9 units
Through tools and methods of user experience research and ideation, Design for Digital Systems uses web-based technologies to create functional prototypes for digital systems. Through demos, exercises, and a team-based trans-disciplinary project, students will use design thinking, industry-standard UX software, and code to identify, propose, and generate novel ideas for user problems. Students will learn advanced HTML and CSS, along with basics of database-driven web platforms using server-side technologies such as PHP and databases. The course is focused on screen-based interactions, but not exclusively so; it considers what technologies are viable today while leaning into the future to solve problems. Experience with HTML, CSS, and JavaScript is recommended but not required. This course replaces 51328 and 51828 Advanced Web Design. There may be a lab fee for non-design students.

51-330 Communications Studio IV: Designing Communications for Social Systems

Spring: 10 units
As the final course in a sequence of studio courses for Communication Design majors, this one builds on everything learned previously. Apply skills/knowledge learned in researching, developing, evaluating, refining communications to multi-facetted communication challenges that warrant the design of multiple communication pieces that span diverse mediums (in print and digital platforms) and function as a system; learn how to design for futuring (parts of the system yet to be determined) and for co-design where parts of the system are made for growth through contributions from audiences. This course is required of Communication Design majors in the School of Design.
Prerequisite: 51-323

51-331 Advanced Calligraphy I

All Semesters: 9 units
This course serves a continuation of study in the discipline of calligraphy. (It meets at the same time as Calligraphy I.) Students may take one of two directions in the course. (1) Enlarging their repertoire of scripts, contemporary or traditional, for use in limited areas of work such as book or display work, or (2) Concentrating on more intensive problem solving using a limited repertoire of scripts such as Roman, Italic, Sans Serif. Prerequisites: 51232
Prerequisite: 51-232

51-332 Advanced Calligraphy II

All Semesters: 9 units
This course serves a continuation of study in the discipline of calligraphy. (It meets at the same time as Calligraphy II.) Students are encouraged to tackle advanced problems or work with the instructor to determine new directions of study. Prerequisites: 51331
Prerequisite: 51-331

51-333 Design Center: Collaboration by Design

Intermittent: 9 units
In Collaboration by Design, we'll be working on improving the ways we collaborate. Through this hybrid seminar/project-based studio, we'll explore ideas to improve collaboration in formal and informal contexts, along with intra-, inter-, multi-, and trans-disciplinary settings. We'll be exploring how issues such as personal values and goals, intimacy and independence, team dynamics, constructive criticism, and others affect the way we work together. Students can expect reading assignments, class discussion, informal (low stakes) writing projects and presentations, and team-based exercises and projects in which we share and apply our learning and develop ideas. Note: students taking this course will help set the topics and curricular trajectory for the course in collaboration with the instructor, so from day one we'll start the work of defining what we'll do, together.

51-336 The Non-Selfie

Intermittent: 9 units
The Non-Selfie: using the camera to record, probe, and understand one's own and another's behavior This course is the opposite of the selfie, but it uses the camera to record human behavior, both your own and another's. Designers need to be good human observers in order to design for human needs. Designers also need empathy. This course aims to deepen sensitivity to others by first better understanding ourselves. Informed by Manfred Max-Neef's classification of fundamental needs and other relevant materials, we will create two in-depth photo-essays, the first being a study of ourselves, the second being a study of someone who is unfamiliar to us. In the first half of this course, while looking at the tradition of self-portraiture in photography and other media, we will be making in-depth photographic stories of ourselves. In addition to photographs, we may make scans of objects, include personal artifacts and anything else that may contribute to building an in-depth self-portrait. In the second part of the semester, we will apply what we learned to a person who we do not know, in hopes of bringing new insights and methods to understanding for another. In addition, we will look at the rich literature that exists in documentary photography about representing "the other." By the end of the semester, each student's work will be made into a hand-made Japanese stab book of two volumes: a volume on oneself, and one on another. The skills learned in this course are immediately relevant to becoming a good designer. Digital camera is necessary, and knowledge of camera operation, Photoshop and InDesign is helpful.

51-338 Documentary Photography

Intermittent: 4.5 units
Documentary Photography: the Social and Built Landscape Documentary photography explores issues, often social, humanistic and/or political, in man-made culture. This course examines the work of nineteenth, twentieth, and twenty-first century documentarians while students photographically investigate their own topics. Among the many ethical areas of a documentarian's concern, the course examines (through looking at the documentary tradition and through the student's own work) the following: the photographer's relationship to the subject; the choices involved in representing the subject; the act of selectivity in framing the subject; the reasons for making documentary photographs; the intended audience for documentary photography; and the appropriate final display of the photographs? Extensive shooting, printing, and library research. Prerequisite: A beginning photography course, or by the permission of the instructor.

51-341 How Things are Made

Fall: 9 units
This course will provide a breadth of knowledge for current manufacturing, materials, and processes encountered in the industrial design field. There will be an emphasis on actual production/manufacture methods and not rapid prototyping methods. The class will consist of various lectures, media, electronic tools, and on-site visits to enable an understanding of how mass production affects design and design decisions. Industrial Design Juniors and amp; Seniors or permission of the instructor.

51-343 Products Studio III: Designing for Complex Products Systems

Fall: 10 units
This course provides a framework for understanding core practices of the product design profession by placing it in relation to other disciplines and their influences on mass manufacture of goods; students will use a design process to identify problem/s, map a process in which tangible artifacts are made to learn more about the interaction between object, person, space, and context Prerequisites: 51-245 and 51-248
Prerequisites: 51-248 and 51-245

51-344 Advanced Digital Prototyping

Spring: 6 units
This course is an advanced course using SolidWorks computer modeling. It is a prerequisite for Production Prototyping. This course is intended for undergraduate Design majors.
Prerequisites: 51-324 or 51-245 or 51-249

51-346 Production Prototyping

Spring: 6 units
This course is the 2nd half of Advanced Digital Prototyping, using your work in SolidWorks to produce hard models. This course is for undergraduate Design majors.
Prerequisites: 51-249 or 51-324

51-347 Drawing from Nature

Intermittent: 9 units
Drawing From Nature This course is about observing and making images of things growing, crawling, flying, swimming etc. Observations will be made firsthand in the field, supported with relevant research in topic areas with the aim of deepening personal understanding of all things biological. Issue surrounding natural forms such as behavior, locomotion, adaptation, the environment and systems will also be investigated. We will work in tandem on refining our abilities in communicating what we discover through the process of drawing. A variety of visualization methods will be covered i.e. analytical drawing, visual notes, and diagramming to name a few. We will be using a variety of basic drawing and digital media to develop our work as we uncover aspects of form, structure and surface. Guest speakers will present work they have done in areas such as botany, biology, and environmental studies to name a few. A majority of the work will be done in the field and will then be developed in the studio. A final project will be assigned that will challenge you to develop a concept along with a compelling form(s) that communicates what you have uncovered about nature to a variety of audiences. This course builds on your experiences from First Year drawing and introduces several more advanced visualization methods. This course is intended for Junior and Senior Design Majors.

51-349 Visual Notation/Journaling

Intermittent: 9 units
Visual notation is the graphic equivalent of taking written notes. While the camera is a valuable and at times indispensible tool for recording what we see, the camera cannot make visible mental concepts. Nor can it discover and display underlying structures, create hierarchies, explain organizational schema or concepts that are not easily seen or understood. This course is about making visual notes in order to become fluent in your abilities to observe, record and interperate. Through daily entries in a journal you will work in several content areas i.e. mapping, natural and built environments and systems to name a few. A good portion of the work in this class will be conducted in the field using the resources available to us such as the museum, zoo and architectural sites. You will also be challenged to incorporate your notes as tools for communicating design concepts, implementing project development and presentations. The course will rely on the use of a variety of simple drawing tools and electronic media. Several visualization methods will be introduced and the work will build on the drawing experiences from First Year drawing. This course is intended for Junior and Senior Design Majors.

51-350 Products Studio IV: Designing Products for Social Systems

Spring: 10 units
This course challenges students to build their own design and research process to identify and frame the scale and scope of a problem/opportunity, and place it in relation to the wider system (social, cultural contexts); projects will require synthesizing a range of inputs to develop proposals for future working and living.
Prerequisite: 51-343

51-352 Product Design: Influences on and trends within: 1900 to Present

Intermittent: 4.5 units
A personal perspective on some of the prominent influences and trends in the field of product design since its inception as a recognized commercial discipline, some 100 years ago. The growth of mass-production, its development from craft-based making origins, the impact of technological developments, two world wars, the presence of visual media and advertising, and other cultural waves and trends all show themselves in the products we design, desire, produce and inspire us. Through a series of talks, readings, presentations and a few guest speakers, the class will take a less-than-formal approach to looking at how we got from where we were then to where we are now. There will be discussions, writings, and a visual, notated journal to track your thinking, express your reactions, and thoughts, and the beginnings of a visual archive to take with you after the course ends. An interest in product as a window into cultural thinking is recommended, but not required. Writing, sketching, and searching skills are recommended for participants. Assessment is based on participation, engagement, and the building of a personal archive. 15 students maximum. Preference given to P track undergraduates

51-355 Experimental Sketching

Intermittent: 4.5 units
Experimental Forms of Sketching fall 2011 Advancing design drawing philosophy and application This 7 week mini course seeks to expand our experiences with interpreting forms of drawing quality within the process of sketching. This approach will explore semantics of rendering with mixed media, sensitivity of representational perspective, form building, and sequence evolution, within drawing developments that stimulate emotional connections with a viewer. Through exploring and testing variables, we will use the nature of drawing behavior processes to expand the interpretive significance of abstract idea forms. These "drawing idea forms" will be represented throughout a range of abstract levels from literal to highly figurative. Interpretations will derive from a variety of themes involving design, life, and nature and expressed on paper as objects, scenes, and story persuasions.

51-357 Stuff That's Optional: People at Play

Intermittent: 9 units
Stuff that's optional: People at play Unlike our necessary work that provides sustenance for self and dependants, our recreation is optional and chosen. Products that support recreation are, likewise, an option. Soccer balls, kayaks, daypacks, fly reels, chess sets, running shoes; for that matter, the entire recreational industry is based on election. Our lives are better off for it; play is good for us. In this studio/ project course we will investigate play as an aspect of human endeavor. There are readings, discussions, and sessions aimed at gaining an understanding of the field. We will then respond by searching out and framing design opportunities, ideate and propose, refine and test. We will make stuff as teams and individuals that help us further define what it means to be humans at play. This course is intended for Junior and Senior Design Majors.

51-359 User Experience Research and Design

Intermittent: 9 units
The course intent is to develop appropriate user experience of tools and technology for a projected time frame or context of use. The need to understand people's stories, their lives, and how they want to live determines what interfaces, products, and systems should be developed. Student teams will work together to create appropriate user interactions and experiences which are supported by the design of tools and/or technology. This integrated course will utilize rapid prototyping as the basis for the creation of these proposed tools and products. This course is intended for junior, senior, graduate level students, Non-Disclosure Agreement and other legal agreements may be part of the requirements. Proficiency in one or more of these visualization methods: freehand sketching, computer visualization in 2D graphics, motion graphics and/or 3D solid or surface modeling. By Instructor Approval if NOT in Design. Please forward statement of intent to Instructor.

51-360 Environments Studio IV: Designing Environments for Social Systems

Spring: 10 units
Develop high fidelity proposals and demonstrations of multi-modal hybridized physical-digital environments based on rich information content and principles of user experience design.
Prerequisite: 51-363

51-361 HyperSENSE: Augmenting Human Experience in Environments

Intermittent: 9 units
We make sense of the world using our bodies, and just as we shape the environments around us, they also shape our experiences and senses. We will look in this course at how we can create physical and digital interactions that bridge the gap between humans and built environments to augment our senses. We will explore and introduce new roles of computational design and making in embodied sense-making, including human perception and cognition. We will apply methods and practices that form the basis for embodied interaction design. We will create projects that materialize these interactions using research-through-design and iterative design methods. Students choose the themes for their final projects or join an ongoing research project. Students in this class will work in groups to create installations in space controlled by human actions or wearable pieces that augment the body. Course deliverables include participating in reading discussions, a main project, and a publishable paper documenting the theoretical approach, creative process and findings. The instructors will help students publish their papers or pictorial in upcoming design conferences if students ask for help. Some possible themes for these projects could be: An installation that materializes a human presence in a remote space; a remote collaboration work tool or a wearable piece that enhances a certain human sense, and/or alters the perception of a specific space.

Course Website: https://embodiedcomputations.org/teaching (https://embodiedcomputations.org/teaching/)

51-362 Environmental Typography: Experiments in Space, Place & Identity

Intermittent: 9 units
This course explores the creative opportunities for typography in the physical environment. Through both individual and team projects, we experiment with dimensionality, material, color, and form. Design experiences that consider scale, interaction, and experimental type. Learn theories, concepts, and strategies related to wayfinding. And lastly, give form to identities through color, material, form, and typographic systems.

51-363 Environments Studio III: Designing for Complex Environment Systems

Fall: 10 units
Provide a framework and tools for designing for environments using experience design methods as a means to address the plurality of digital/physical hybrid environments
Prerequisites: 51-268 and 51-265

51-364 Drawing Spaces

Intermittent: 9 units
The natural and built environment will comprise the subjects of inquiry in this course. We will investigate systems of spatial and physical organization as found in the landscape in various forms and structures from forest to farm and from tent to tenement as examples. The intersection of these systems found in accessible locals will be investigated in the field through on site drawings using simple media and sketchbooks. These studies will then form the basis for the iteration of more developed images depicting environments both existing and imagined. Some time will be spent on observing people and various life forms as they populate and interact within these spaces to various ends.

51-365 Creative Technology Sprints

Intermittent: 9 units
In this course, we will take computational approaches to explore information design in space. Students will consider the interactivity and readability of information when creating data-driven systems. They will learn Javascript programming and use P5.js for their interactive systems. There will be three projects: 1) Speech-responsive Kiosk; 2) Immersive Space using Projection; and 3) Data Visualization using Holo Lens. There is no prerequisite for this course, but basic understanding of typography and information design is expected.

51-367 Design Center: Computational Design Thinking

Intermittent: 9 units
In this course, we will explore creative coding in the context of communication and interaction design and use it as a primary medium to consider form, content and context for designing systems. Specifically, we will use computation as process and material for perceiving and generating forms through crafting the relationships between input and output. In other words, we will create artifacts computationally by designing formations through constructing algorithms and manipulating parameters for recognizing, deconstructing and generalizing patterns across solutions. There will be three group projects to explore the following concepts: 1) Rhythms and Patterns, 2) Structures and Relationships, and 3) Conditionals and Events. There is no prerequisite for this course, but strong understanding of typography, grid, and visual system is expected. In addition, since coding is an integral part of this course, it is assumed that you already have prior experience with programming or will spend time outside of class to learn and understand the basics on your own (links to online tutorial videos will be provided).

51-368 Moving Pictures

Intermittent: 9 units
The objective of this course is to provide students with a practical, technical and theoretical foundation in video work. Students leaving this class will have gained knowledge of developing a moving picture from start to finish. Students will learn how to storyboard/scamp, plan/scout, produce, and post-produce. Equally importantly students will develop their own visual esthetics through the creation of 4 short videos.

51-369 You Are Here: Identity & Place

Intermittent: 9 units
Join us to explore how designers can express the identity of places, help people navigate complex environments, and craft memorable experiences. We will spend the semester experimenting with type, color, and pattern, while pushing beyond the boundaries of 2D surfaces to also consider materiality, dimensionality, and the environmental context. We'll also learn and apply theories of wayfinding, make custom typography and utilize it to design a variety of artifacts, and discover something new about the people and places around us.

51-371 Futures I

Fall: 4.5 units
The Futures 1 course focuses on aligning near term design action with longer time horizons aimed at sustainable futures. We introduce the students to Dexign Futures. Dexign is defined as "an experimental type of design that integrates Futures Thinking with Design Thinking." A distinguishing feature of dexign in our usage is the focus on aligning current action with long-term sustainability goals. The course covers different approaches to interpreting the future: from the extrapolations of trend forecasting, through the risk assessments of scenario planning, to attempts to steering the present through backcasting. Students explore the future through utopian and dystopian fictions that are created by authors, filmmakers and themselves. Students also attempt to evaluate futures in terms of their longer-term consequences.

51-372 Persuasion

Spring: 9 units
Examine written argumentation, oral presentations, artifact exhibitions, but also branding and social media. Students learn how to position their design ideas and connect them to the people and organizations that will increase their perceived value to target audiences. A focus of the course is on argument by precedent, where students build the significance of their innovations by situating them historically.

51-373 Futures II

Intermittent: 4.5 units
This course, paired with Futures I (51371), is the second half of a semester-long deep dive into foresight/futures for emerging designers. It represents a turn from learning basic concepts and methods in the futures field, toward more advanced, applied approaches at the cutting edge of strategy, co-design, worldbuilding, and transmedia storytelling.

51-374 Preparing for Design Practice

Intermittent: 4.5 units
This course helps design students formulate individual plans for their professional practice. In a ramp-up to Confluence, the first half of the class is devoted to developing and organizing portfolios, writing and designing resumes and cover letters and practicing interviewing skills. After Confluence, the second half is devoted to self-evaluation and reflection, guest lectures by early-career and later career designers and field trips that explore various aspects of a professional design career as well as other post-graduate opportunities. This course is geared towards Seniors and MA students, but Juniors applying for internships are also welcome.

51-375 Meaning in Images

Intermittent: 4.5 units
Images abound in our culture. This course takes a critical look at many different kinds of photographic images to understand how they operate in our culture to inform, persuade, and entertain various audiences. The content for this course will be generated from looking at, thinking about and discussing issues discovered while studying well-known to lesser-known images that range from photographs used in ad campaigns, to photographs that are used in scientific representation, to snapshots in family photo albums, to photographs that are used to show social injustices, to photographs that exist in museum collections. Readings will be assigned and short writing exercises will be required throughout the semester. In addition, photography assignments will be given. Design majors will have preference. Requirement: a digital camera. 15 students, junior and senior Design Majors.

51-376 Semantics & Aesthetics

Intermittent: 4.5 units
The course will explore the principles of visual composition, proportioning systems and the rules of order as it relates to art, architecture and design. The class will involve extensive reading and discussion of these topics in class. Some project work will also be required but minimal to the reading. A reading list will be provided. Instructor permission required for non-Design majors.

51-377 Design Center: Sensing Environments

Intermittent: 9 units
Whereas UX Design is typically described as shaping the immediate environment between a user and an object/interface, this course will instruct you in techniques, methods, and vocabularies to expand the scale of your design. Course content will give students experience integrating and shaping their current work into 2-3 other levels of scale, such as a single room, building, campus, and neighborhood. Students will walk away with an understanding of environments that will expand their range of capability, fitting for interdisciplinary application within fields such as social innovation, community development, public policy, architecture, and urban design.

51-378 Developing Form with Sketches & Models

Intermittent: 4.5 units
Development of Form with Models and amp; Sketches

51-379 Spatial Computing Design

Intermittent: 9 units
In this class, we will use Motion Tracking and Spatialized Outputs to design spatial computing experiences-collective, distributed, and localized interactions in a physical environment. We will work in a classroom instrumented with infrared cameras, digital projectors, and Sound Hologram technology (Wave Field Synthesis). In Unity 3D and using a digital twin of this classroom, we will program the interactions (in C#) to be tested in the physical space. Although some of these technologies relate to AR and VR systems, we will create experiences in the physical world without the interference of screens, headphones, and/or headset devices. This project-based class focuses on advancing research through prototyping and testing working implementations. The class sessions are structured around tutorials, short lectures, working sessions, and reviews.

51-380 Experiential Media Design

Intermittent: 9 units
Experiential Media Design focuses on the theory, methodology and history behind the design, development and interpretation of experiential media systems. The class incorporates a multidisciplinary approach to the study of complex media systems as technological, political, economic, socio-cultural and personal experiences. Topics covered include media and communications theory, cultural studies, qualitative and quantitative methodology, design principles, human-computer-interaction, information visualization and representation, user studies and evaluation. Students will create and critique a variety of integrated media systems demonstrating technical competence, aesthetic knowledge, analytic rigor and theoretical relevance. This class is open to Junior and amp; Senior Design Majors, and others by permission of the instructor.

51-382 Design Center: Design for Social Innovation

Spring: 9 units
Design for social innovation is a seminar that traces the history and application of design methods to solving social problems. The course will weaver together themes from readings in design, business, public policy, technology, social service, international relations and current events. The course will review examples of successful and failed social innovations from local, regional, national and international contexts. Students will learn the role of governments, technology, funding, infrastructure, mindset, emotion, and cultural factors in addressing problems in the social sector. The course will include a real-world problem-solving component where students (in teams or individually) will write a paper, design an artifact or intervention, propose a project or conduct a short design research study that addresses a real-world problem that impacts a local community.

51-384 Design Center: Co-Designing for Social Innovation

Intermittent: 4.5 units
This course is for students considering how their work can contribute to a positive societal shift. Through a mix of lecture, readings, classroom activities and short field assignments, the course covers models of change, and methods, approaches, and skills that support the emergence of new social patterns. Such work necessarily involves diverse stakeholders, the complexity of human relationships and beliefs, and the challenges of power, conflict, exclusion and inequity. For that reason, this course helps students make first steps in preparing to facilitate creative change among diverse stakeholdersattending to the conditions for generative dialogue, listening to all voices, and hosting the long process of co-creation.

51-385 Design for Service

Intermittent: 9 units
We all have an idea of what a good service is and #8212; when everything clicks into place, when you feel a little surprised and delighted because of the thoughtfulness and smoothness. And we know what it's like when a service goes wrong and #8212; missed flight connections, sitting for too long in a doctor's waiting room, continually repeating information as you're passed around customer service representatives. So what does it take to get a service right? And how can our services best help us get things done across multiple channels? We will explore the fundamentals of service design in this project based course. This includes the tools and practices of service design, and using service design to both analyze and improve existing services, as well as develop new, compelling services. Our goals (and the objectives of this class) will be to learn service design fundamentals by hypothesizing, experimenting, building, testing our assumptions, pivoting, tweaking, and improving. Some great visitors will join us too, in person and virtually, to provide real-world insights about service design. This course utilizes interdisciplinary and mixed-cohort teams to replicate the experience of working as a service designer.

51-387 Introduction to DeXign Futures

Intermittent: 9 units
As corporations, governmental organizations, and civil associations face accelerating change in uncertain times, increasingly they are looking to designers for new ways of thinking and acting. Designers today are engaged as thought leaders, strategists, activists, and agents of change in complex socio-technical problems throughout private, public, civil and philanthropic sectors worldwide. For designers trained to shape futures defined by uncertainty and change, these exponential times represent unprecedented creative opportunities for innovation. In this course, students learn the basic design skills necessary explore the forces that drive change in the future and learn to align innovation strategically with the trajectories of those forces.

51-389 Typeface Design : Variable

Intermittent: 9 units
There is a lot of expression in font files... The challenge is in getting the possibilities out. Relatively speaking, the tools used to craft, produce, and publish typographic forms have never been more plentiful nor more accessible. Computation has fused with form-making and generative processes creating limitless formal, practical, and conceptual potential. Kinetic and dynamic surfaces and screens abound alongside the continued stabilization of variable and color font formats. Unlike experimental font formats of the past, these emerging tools have seen ever-increasing community use, adoption, and advancement. We are in the midst of a (variable) typographic tidal wave. One which will have an unfathomable impact on *how* we communicate and *who* is able to communicate. This is a special topic studio elective on variable (and color!) fonts; from methodologies to visualize variable design spaces to the practical know-how needed to craft them. We will specifically explore variability in relation to the production of type, and curiously chart the number of ways in which the tools/programs of type production can be used (and mis-used) to animate forms (letters or otherwise) in endlessly generative ways. We will navigate the relationship between the history of code, and the history of font production, to find ourselves making within the current context of variable, and color, type technologies. Primarily a studio-centric 'off-road typography' making and prototyping environment, the course's critical dialogue will focus on the transformation of language and communication through these variable design processes.

51-390 Social Interaction Design in Community

Intermittent: 9 units
The course looks at Design for Social Innovation principles and practices, Documentary Photography, and Design Research while walking the streets, talking to residents, and working with organizations in a Pittsburgh neighborhood to understand its challenges. Students will examine Social Design case studies, with a focus on Problem Reframing processes (Dorst), and Solution Amplification (Manzini), and various design-enabled Theories of Change. They will also explore histories and theories of Documentary Photography. For the project/ethnographic portion of the class, students will work in teams of two within a neighborhood, and partner with residents and organizations. These collaborations will help students see the challenges of the community from an insiders point of view, in order for them to design appropriate responses to some of those challenges.

51-392 Images and Communication

Intermittent: 4.5 units
No one doubts the value of photography as a means of recording life. Even if we don't think of ourselves as photographers, digital cameras make it easy to photograph our families, our trips, and aspects of our life that we want to remember. But beyond snapshots, can photography also teach us how to see? And how do they teach us about the world? And, what are the qualities inherent in photographs that make them effective as artifacts of communication? Does looking through the camera's viewfinder sensitize us to world and help us see more? Or, as some writers suggest, does the camera interfere with experiencing the world fully. This course explores seeing with the camera and the many issues that arise when one snaps the shutter. We will be looking at a range of different kinds of photographic images, understanding their contexts, and how to read them. Designers and other visual people use photographs extensively in their work. This course endeavors to make students more aware of their decisions and actions when making photographs as well as how to judge a photograph's effectiveness. The issues that we discuss using photographs, relate to other kinds of visual images, as well. We will be making photographs as we are discussing critical issues in photography that come out of readings. Students must own a digital camera but no prior photographic experience is necessary.

51-393 Design Studies: Object-Based Histories at the Museum

Intermittent: 4.5 units
Object-Based Histories utilizes as its primary source Extraordinary Ordinary Things, the design collection installation of more than 300 works at Carnegie Museum of Art. In a small group setting students in this elective will consider historic and contemporary designs within the museum galleries. Through close looking and conversation, we will explore designers, makers, and users and their various cultural contexts. This course takes a its premise that if objects in the world are solutions, we can learn to intuit the questions. In so doing, we gain insights into human nature, cultures, and the built environment. Students will expand their knowledge of design histories, materials, and technologies and hone their skills in visual analysis, historical imagination, and critical thinking.

51-396 Design Center: Design for Zero Carbon Lifestyles

Intermittent: 4.5 units
In this mini-course, students focus on aspects of Sustainable Development Goals: #13 Climate Action, #12 Responsible Consumption and Production, #11 Sustainable Cities and Communities, #9 Industry, Innovation, and Infrastructure, and #7 Affordable and Clean Energy. Students explore how to become the agents of change around the challenges of the climate emergency focused on the design of zero-carbon lifestyles. Projects focus on zero-carbon lifestyles on two levels: individual and campus life. This course is open to all kinds of designers ranging from architecture, art, business, computer science, HCII, engineering, psychology and so forth.

51-399 Junior Independent Study

All Semesters
Guidelines for independent study in the Design office. Proposals must be approved by faculty before registration.

51-400 Transition Design

All Semesters: 9 units
Transition Design: Designing for Systems-Level Change. This course will provide an overview of the emerging field of Transition Design, which proposes societal transitions toward more sustainable futures. The idea of intentional (designed) societal transitions has become a global meme and involves an understanding of the complex dynamics of socio-technical-ecological systems which form the context for many of todays wicked problems (climate change, loss of biodiversity, pollution, growing gap between rich/poor, etc.).Through a mix of lecture, readings, classroom activities and projects, students will be introduced to the emerging Transition Design process which focuses on framing problems in large, spatio-temporal contexts, resolving conflict among stakeholder groups and facilitating the co-creation, and transition towards, desirable, long-term futures. This course will prepare students for work in transdisciplinary teams to address large, societal problems that require a deep understanding of the anatomy and dynamics of complex systems.

Course Website: https://transitiondesignseminarcmu.net/

51-418 Diversity, Equity, Inclusion and Design

Intermittent: 9 units
In this course, students will explore Diversity, Equity, and Inclusion (DEI) issues as they relate to the School of Design to propose and possibly implement and initiate efforts to begin to address some of these issues. We will learn about the systems, structures, and tools for, by, and with Design at the intersection of DEI. Foundational lectures, discussions, and hands-on workshopscombined with a review and consolidation of precedent research and work supporting the definition and scope of DEI. Through a variety of group exercises, directed working sessions, guest lectures by subject matter experts, readings, case studies, and more, students will be guided through an intensive learning process. Students will work individually and collaboratively, including working with the full course cohort. We will ask questions such as: What do we mean by DEI? What are the opportunities and challenges within the design discipline and its pipelines? Within design pedagogy and practice? With designers and designing? What happens if we put DEI at the center of our work? How do we develop new postures and mindsets that place DEI at the forefront of the School of Design at Carnegie Mellon University?

51-419 Design Center: Design's Reverberations: Ripple Effects of Innovative Ideas

Intermittent: 4.5 units
When an idea is implemented to effect change, what happens to its context? This course provides students from different backgrounds with the opportunity to think through multiple dimensions of and orientations to the notion of solving a problem through making and theorizing. Through the lens of design-driven processes, the class will delve deeper into the conditions in which problems are solved and place focused attention on domino and ripple effects of effecting change. Students will uncover what may be brewing underneath the surface of a given context, such as the residual impact of historic events, changes to the topographical landscape of a neighborhood, connections between individual behavior change to the growth of niche cultures, sensorial shifts in the environment due to climate change, emerging instabilities in a system sparked by the implementation of an idea, amongst others. Students will use present-day contexts, such as neighborhoods or particular initiatives, as points of departure to answer the questionswhen an idea is implemented to effect change, what happens to its context? Students in this course will gain a deeper understanding of the complexities of instigating change to inform their ethos and practice.

51-420 Sensing Place through Color

Intermittent: 9 units
The world is enhanced by color in every facet of our environment, but we often overlook unimaginable color interactions. The application of color depends mainly upon a trial and error process of selection, comparison, interaction, and evaluation. This course is about learning to look at the world with color filters and exploring ways to utilize color in new and meaningful ways. Through a series of prompts, journaling exercises, and personal experiences, we will reimagine our sense of place through color.

51-421 Design Center: Data Visualization

Intermittent: 9 units
This is a comprehensive data visualization primer. In Data Visualization course students will learn how to parse and visualize data. Starting with multiple introductory exercises on the foundations of data viz, we will then investigate tools, principles and best practice by which computational design driven data visualizations are operating today. Then, students will decide on a data set of their choice (necessary complexity given), to either create a data visualization with an emphasis on telling a story, or to generate a meaningful data art piece with an emphasis on engagement and experience. Project outcomes can be expressed through a variety of forms of the students choosing, from print posters, websites to mind-bending interactive experiences. These will be documented and presented on the final crit. This course assumes that students are already familiar with elementary programming (in any language), such as for() loops, if() statements, arrays[] and functions(). Participants will use Javascript and very likely popular creative coding toolkits like p5.js, Basil.js, Snap.svg, GSAP, D3.js etc. for their projects.

Course Website: http://bit.ly/CMUDataViz (http://bit.ly/CMUDataViz/)

51-423 Pieces 2.0: Social Innovation: Desis Lab

Intermittent: 9 units
In this class, students will identify a social problem and take a holistic design approach to solving it. They will design a product/product line- anything from a set of tools to help older adults lead a more active lifestyle, to re-envisioned collateral for the Lupus Foundation Pennsylvania. After or in tandem with the creation of this product, the student will construct an image, which will entail print media, a Web presence, packaging, and photography. By creating the product and its "marketing" effort from top-to-bottom, the student will gain a diverse set of skills in design as well as a richer understanding of the product. In the end, all the pieces will come together to create a well-refined image.

51-424 Web Portfolio

Intermittent: 4.5 units
This course will provide an opportunity for students to design and code their online portfolio. The course covers basic elements of Web design along with the foundations of HTML, CSS, Javascript and Flash as components of the design process. Prior experience with HTML is encouraged but tutorials will be provided if necessary. This is not an Actionscript programming course.

51-425 Design Center: Beginning Book Arts Lab

Fall and Spring: 6 units
This is a class of basic issues regarding hand bookbinding and letterpress printing. It's purpose is to develop a basic structural sense of book forms, of flat format work and of three dimensional forms. Learning hand craft techniques, developing hand skills and the sensitivity to materials are also a goal. Binding projects assigned will target the unique nature of papers, fabrics and archival card-boards. Structural procedures and techniques will be identified with each assigned binding project. The binding projects will be: A hardcover for a paper back book, a single signature book, a multi-signature book with flat spine, and a box construction. The box project is designed and crafted to contain a small letterpress printed class edition, either in book form, or as a set of un-bound pages. The letterpress component teaches the standard issues, unique to the relief process, in press work, handset procedure of cast metal type, page form spacing, lock-up of pages in press, proofing, and production printing. Each semester a small class edition project of text content and image, in two-color registration, is designed, hand set and printed. Image generation can be by hand cut block, assembled type-high forms, or digital process to polymer plate. This class is not to be repeated.

51-426 Design Center: Beginning Book Arts Lab

Spring: 6 units
Beginning Book Arts Lab Class. 6units. (This class is a prerequisite for the Advanced Book Arts Workshop Lab Class). This is a class of basic issues regarding hand bookbinding and letterpress printing. It's purpose is to develop a basic structural sense of book forms, of flat format work and of three dimensional forms. Learning hand craft techniques, developing hand skills and the sensitivity to materials are also a goal. Binding projects assigned will target the unique nature of papers, fabrics and archival card-boards. Structural procedures and techniques will be identified with each assigned binding project. The binding projects will be: A hardcover for a paper back book, a single signature book, a multi-signature book with flat spine, and a box construction. The box project is designed and crafted to contain a small letterpress printed class edition, either in book form, or as a set of un-bound pages. The letterpress component teaches the standard issues, unique to the relief process, in press work, handset procedure of cast metal type, page form spacing, lock-up of pages in press, proofing, and production printing. Each semester a small class edition project of text content and image, in two-color registration, is designed, hand set and printed. Image generation can be by hand cut block, assembled type-high forms, or digital process to polymer plate. This class is not to be repeated.

51-427 Advanced Book Arts Workshop

Intermittent: 9 units
Students will be required to plan and design projects that relate to binding, or digital printing, or letterpress printing, or hand-setting of cast metal type. Projects utilizing a combination of all processes can be planned as well. Experimental work, or Artists' Books are also encouraged. In this class structure students will be able to plan and design projects that are complete books, with printed content, or with out content. Other flat structures, and three dimensional containers are examples of general forms that will be categorized as binding work. Students who wish to enroll in this course must have already taken Beginning Book Arts, and must also speak to the instructor directly about project ideas. Emphasis for binding is working independently with a greater level of hand craft and a sensitivity to materials. Emphasis for letterpress printing is to learn in depth, and master, the general mechanical process for doing press work. Emphasis for hand typesetting is on gaining an understanding of the system of cast metal type, and to develop a sensitivity to typographic principles. Instruction will be given on an individual basis through consultation at strategic times throughout the semester. Project evaluation will be based on the success of the project work compared to each student's written project proposal at the start of the semester. The Advanced Workshop in Book Arts can be repeated. For more complex project work this class can be continued for the following semester.

51-428 Time, Motion and Communication

Intermittent: 9 units
This course focuses on designing and presenting time-based messages on screen. The differences between paper-based and screen-based communication are discussed and become departure points for projects. Working with word, image, sound, and motion and #8212; in Adobe AfterEffects and #8212; students develop responses to a variety of project briefs. Brief histories of animation, experimental films, and title sequences, as well as experimental music provide conceptual models to our discussions. An attitude of exploration is stressed, with an emphasis on visual voice, performance, and communication. Content will include personal messages and timely information. Proficiency with AfterEffects is a firm requirement. Preference will be given to junior and senior Design students.

51-430 RE.Futuring Craft

Intermittent: 9 units
This course explores the role of craft objects in shaping material culture and material futures aiming to offer propositional and speculative concepts to future-cast craft objects within natural, societal political, economic, scientific, and technological systems. Students engage in project-based learning that simulates diverse future scenarios to critically analyze material trends and their impact on future hand-crafted product design

51-434 Experimental Form

Intermittent: 9 units
The Experimental Form Studio looks broadly at the discipline of industrial design with an emphasis on creating new paradigms for interactive objects. This course encourages an exploratory study of physical objects and artifacts and provides a creative and intellectual forum to re-imagine our relationship with objects. Each independently-themed project presents opportunities to consider embedded mechanics and technology, objects as interactive media, and experience-driven design. Experimental Form, at its most basic, is a process that blends play and inquiry in an open-ended way finding the unexpected through tinkering and trying something you don't quite know how to do, guided by imagination, curiosity, and a disciplinary skillset. In this sense, Experimental Form complements the core Product Design Studio sequence by providing a playground for intellectual discourse, experimental trial and error, and refining individual processes for designing.
Prerequisites: 51-343 or 51-311 or 51-248

51-436 Designing w/CARE:Co-Creating Solutions for Complex Care Coordination in Oncology

Spring: 9 units
What does providing healthcare to patients with complex care coordination needs mean? How do we build processes and systems to ensure patients and family members receive the care they need and want? How can design thinking help healthcare institutions improve population health, reduce costs, enhance the care experience, including the care team's well-being, and advance health equity? How can we design effective communication systems to foster patient-centered care throughout the continuum of care for all patients? It is a tremendous opportunity to gain first-hand experience through interactions with healthcare providers, patients, and their caregivers. Students from various disciplines can apply their knowledge and perspective to propose a solution for a real-world healthcare problem.

51-437 The Emerging Ecological Worldview

Intermittent: 9 units
In this seminar it will be argued that the mechanistic worldview which has permeated Western (and Westernized) thinking and society since the scientific revolution has been crumbling for several decades: its place is gradually being taken by an emerging ecological (or holistic) worldview. This worldview coheres themes such as relationality, interdependence, self-organization, diversity, pluralism, creativity, context, process and wholeness. These themes have in many ways been embodied in the evolution of natural systemsorganisms, ecosystems and the earth itselfand have enormous implications for how we inhabit the places in which we live and the planet as a whole, if we and the 'More-Than-Human World' are to flourish. We will ask what it means to 'think ecologically' and what are the implications of the ecological worldview for how systems of all kinds (technological, infrastructural, political, social, economic) are designed. Students will explore how the application of ecological principles can help us to more authentically 'inhabit' and satisfy our needs in the places in which we live, and inform strategies for designing for futures that are more sustainable, equitable and desirable

Course Website: https://docs.google.com/document/d/1l_J7yptD8-MWKsaI9SZZdRKSqmscedSHsSH3TLbSVjs/edit?usp=sharing (https://docs.google.com/document/d/1l_J7yptD8-MWKsaI9SZZdRKSqmscedSHsSH3TLbSVjs/edit/?usp=sharing)

51-438 Letterpress/Screen-printing DIY Workshop

Spring: 9 units
This hands-on class concerns creativity in two of the most essential print mediums. The Print Workshop is an opportunity to form a foundation of letterpress and screen printing arts. Within the studio space, you will have the chance to use equipment used within the art community today and some rare tools that only students of this class will have access to. You will learn the history and skills to safely navigate the 2/D Lab and the confidence and knowledge to make zines, posters, t-shirts, greeting cards, and more.

51-441 Foundation of BME Design

Fall: 6 units
This course focuses on the Product Development scope and framing of a new medical device. Students will work together in an interdisciplinary team with Biomedical Engineering students to identify medical professional or patient needs through behavioral research and participatory research methods. This course deliverable requires the team to propose the problem space and develop a design brief and plan for the following Spring semester to implement. Prerequisite: Junior level design or higher with studio training. Solid modeling or surface modeling recommended.

51-442 BME Design Project

Spring: 9 units
This course is the second in sequence of prototyping and testing a proposed medical device product. The course consists of modules for the development of a project plan, background research, hazard analysis, setting product specifications based on user requirements, detailed design and analysis, prototype development and final documentation and presentation. All products developed will respond to the needs of appropriate market segments; resulting products will be deemed safe, effective, useful, usable and desirable by those segments. Students will produce a form model, functional prototype, marketing plan, and manufacturing plan of their product. Prerequisite: 51-441 (3 units, Fall) Foundations of Biomedical Engineering Design (or permission of the instructor). Junior level design or higher with studio training. Solid modeling or surface modeling recommended.

51-446 Design For Aging

Intermittent: 5 units
The population is aging at a staggering rate. Though not the only factor, the last of the baby boomers (b. 1946-1964) are turning 60 this year (the oldest boomer turning 78). Similar aging statistics apply in the US and internationally. Implications for design are evident. Ignoring this segment of the population in the design decisions we make would not only be socially and physically detrimental; it would also overlook an enormous opportunity. In this course we will examine the broad scope of aging with an inclusive intent already established through the premise of universal design. This means challenging assumptions and stereotypes, recognizing the enormous diversity in how people age. Through readings, other media, guests, and direct hands-on experiences, we will understand and gain an appreciation for the range of changes that occur with aging, including physical and cognitive abilities, social and emotional wellbeing. While we will learn from other disciplines, the focus will be on implications for the design of products, communications, environments, and conditions for interactions in and with the world.

51-451 Fundamentals of Joinery & Furniture Design

Fall: 9 units
Intensive introduction to traditional joinery techniques and the properties of wood through the use of textbook studies and lab experiments. Emphasis placed on how these techniques and properties influence design decisions. Students will learn how to set up, sharpen and use traditional hand powered tools. This acquired knowledge will be applied in the design and realization of a piece of wooden furniture. Limited enrollment. Lab fee and material purchases required.
Prerequisite: 51-350

51-452 Furniture Design II

Spring: 9 units
A continuation of 51-451, this course explores a much broader range of issues related to furniture design. Students will identify and define in a proposal the area of furniture design they intend to investigate and then produce one or more furniture pieces developed from their findings. Materials and processes applied to the project are limited only by the resources the student can bring to bear. Assigned readings and a series of in-class discussions will focus on the influence of workmanship in design, and on how the behavior of the user is influenced by the form or esthetic language of the artifact. Lab fee and amp; material purchases required.
Prerequisite: 51-451

51-455 DeXign the Future: Human Centered Innovation for Exponential Times

Intermittent: 9 units
DEXIGN THE FUTURE: Human Centered Innovation for Exponential Times
As corporations, governmental organizations, and civil associations face accelerating change in uncertain times, increasingly they are looking to designers for new ways of thinking and acting. Designers today are engaged as thought leaders, strategists, activists, and agents of change in complex socio-technical problems throughout private, public, civil and philanthropic sectors worldwide. For designers trained to shape futures defined by uncertainty and change, these exponential times represent unprecedented creative opportunities for innovation. In this course, students explore methods and tools for design in exponential times to shape uncertain futures. Students will explore the forces that drive change in the future (i.e., social, economic, political, environmental, technological), and learn to align innovation strategically with the trajectories of those forces. The design project that drives everything else is the future of mega-metropolitan regions, the hubs of innovation where 70% of people in the world and 75% of Americans will live in 2050. In the semester long project, students create scenarios for Life 2050 in Metro 3.0, using Pittsburgh as a locus and focusing on a project within urban systems such as Sustainable Production and amp; Consumption, Lifelong Learning, Human Development and Resilient Community.

51-471 Design Center: Imaginaries Lab: Research through Design

Fall: 9 units
The Imaginaries Lab is a research studio developing design methods to explore and support people's imaginingboth new ways to understand, and new ways to live, in an increasingly complex world. This course, running over three weekends, immerses you in a creative 'research through design' project, including prototyping and using experimental design methods 'in the wild', and in depth. You will learn and develop a variety of tools for conducting innovative forms of research through design, including exploring how people think, understand and imagine complex social and technological concepts, and envision futures, and depending on your expertise or interest, will be able to concentrate on applying particular skills as part of multidisciplinary teams. For example, a project might include speculative design, ethnographic inquiry, physical computing, and novel creative methods. We will aim to turn your work into a published output for a conference or journal, so there is additionally the opportunity to gain experience in this aspect of academic research.

Course Website: http://imaginari.es

51-478 Speculative Critical Design

Intermittent: 9 units
This praxis-based course will actively engage futures research through the integration of findings from critical readings, ethnographic research, mediated storytelling and hybrid prototyping. Using techniques of inversion, defamiliarization, uncertainty scenarios, everyday practice and good old-fashioned humor, we will create objects, systems and experiences that stimulate conversation, debate and understanding. The course seeks to produce a diversity of 'what will?' and 'what if?' cultural provocations that deeply examine possible, unwanted and seductive futures. This course is open to Junior and Senior Design majors, or by permission of the instructor.

51-480 Design Capstone Project

Spring: 12 units
Learn how to work independently, applying skills/knowledge in Products, Communications, Environments to the research/definition/development/testing of a project that focuses on the design of a service or social innovation that warrants investigation; deepen understanding of service and amp; social innovation design principles and how they are put into practice.
Prerequisite: 51-481

51-481 Senior Design Studio

Fall: 12 units
As contributors to the built world, the School of Design recognizes that designers can significantly impact society and embrace the responsibility to propose new ways of seeing and exploring the numerous dimensions of any given problem space. This studio is the next stage of that preparation. Structured into three separate discipline sections communications, products, and environments each will continue to leverage and evolve its disciplinary practices, ways of working, and purview to develop positive and impactful design proposals.
Prerequisites: 51-350 or 51-330 or 51-360

51-483 Debating the Roles & Responsibilities of the Designer

Intermittent: 9 units
Designers are expected to play a role in creating aspirational lifestyles through products and services, and informing and influencing human behavior on small and large scales. However what impact does or should the designer have on our lives, our society, and culture? Through readings, discussions, and team activity, students will construct pro and con arguments and debate the role and responsibility of the designer in a critical and fun way.

51-485 Design Center: Imaginaries Lab: New Ways to Think

Intermittent: 4.5 units
In this course, we'll carry out 'research through design' projects using experimental investigative methods in the wild, focusing on new ways to think and understand in an increasingly complex world. Learn and develop a variety of tools for conducting innovative forms of research through design, focused on exploring how people think, understand and imagine complex social and technological concepts, and envision futures. By the end of the course students will have worked on an interdisciplinary research project, including with an external partner, drawing on a number of disciplinary domains, and have experience with different kinds of design research and practice, from speculative and critical design to participatory design, as well as developing the skills and experience necessary to innovate with, and deploy, those methods. This course is a complement to 51-487 Design Center: Imaginaries Lab: New Ways To Live, but is independent of it, and eitheror bothcourses can be taken without overlap (we will be doing different projects, with a different focus).

Course Website: http://imaginari.es/newways (http://imaginari.es/newways/)

51-486 Designing Experiences for Learning

Intermittent: 9 units
This course focuses on designing experiences that engage people in educational activities that enhance their learning through meaningful, memorable, and enjoyable interactions with information. Throughout the course, students investigate the intersection of design thinking, UI/UX design, cognitive studies, social sciences, instructional design, and educational pedagogy as a way of developing knowledge and skills in designing experiences for learners. Students study topics that are often difficult to grasp and collaboratively build a taxonomy of content types based on common and differentiating characteristics to identify design opportunities. Through readings, projects, and class exercises, students explore how people perceive and process information, what motivates them to learn, and what constitutes an experience. The course introduces students to traditional and emergent learning tools and methods as a means of defining affordances and limitations of various learning approaches and mediums. It also provides students the opportunity to apply what they learn through the design, testing, and assessment of learning experiences that they create.

51-487 Design Center: Imaginaries Lab: New Ways to Live

Intermittent: 4.5 units
Focusing on new ways to live and experience the world, now and in the future, we'll do practical investigative 'research through design' projects using experimental methods in the wild. Learn and develop a variety of tools for conducting innovative forms of research through design, focused on exploring how people think, understand and imagine complex social and technological concepts, and envision futures. By the end of the course students will have worked on an interdisciplinary research project, including with an external partner, drawing on a number of disciplinary domains, and have experience with different kinds of design research and practice, from speculative and critical design to participatory design, as well as developing the skills and experience necessary to innovate with, and deploy, those methods. This course is a complement to 51-485 Design Center: Imaginaries Lab: New Ways To Think, but is independent of it, and eitheror bothcourses can be taken without overlap (we will be doing different projects, with a different focus).

Course Website: http://imaginari.es/newways (http://imaginari.es/newways/)

51-489 Design Center: Designing Narratives Across Media

Intermittent: 4.5 units
This studio mini will deal with designing at the intersection of three things: developing rich worlds, i.e. experiences and narratives, understanding how different mediums work and what they do, and understanding how genres work in terms of conventions around content and form. Students will thus be exposed to thought from various disciplines like media, genre, literary and cultural theory in order to create rich, interactive worlds as part of a single design studio project. Specifically, we will be analyzing and reflecting on the phenomenon of interactivity by studying how mediums like interactive print, film and cinema, tangible board/tabletop games, and installation art can be employed using the frame of "Other" futurisms (sinofuturism, afrofuturism, indofuturism etc.) that are part of the general practice of speculative and science fiction throughout the world. We will engage with popular and fringe cultural texts and artifacts, so students should be prepared to spend time watching movies, playing games, reading books etc. in an analytic, reflexive manner in order to better understand the different strategies that authors have developed in order to evoke specific responses in their audiences. In this class, you will bring the technical skills required - the object will be to collaborate with others with complementary skill-sets in order to create one lavish, intricate transmedial project that will draw people into the depth of its world. This is not an art class - we will discuss the designerly applications of this type of work, particularly with reference to design studies, speculative/critical design, ontological design, and decolonial design. The object of the course will be to make "other" ways of designing in the world visible and experiment with the boundaries of design as a practice of cultural production.

51-493 Design Center: Decoloniality: Past, Present & Future

All Semesters: 4.5 units
The relevance of decoloniality in design. The role of media and technology in shaping and advancing particular ways of understanding the world The future of decoloniality: where do we go from here?

51-494 Design that Lasts

Intermittent: 6 units
Never have we wanted, owned, and wasted so much "stuff." Our consumptive path through modern life leaves a wake of social and ecological destruction. Sneakers worn only once, forgotten smartphones languishing in drawers, and abandoned IoT devices promising solutions to problems that don't exist. By what perverse alchemy do our newest, coolest things so readily transform into meaningless junk? This design elective investigates why we throw away things that still work, and shows how we can design products and services that last. This is a studio class, with a substantial theoretical thread woven through it. We will therefore spend about half our time on lectures, readings, and debates, and the other half on studio practice, project coaching tutorials, and group critique. The result, a journey toward an experience heavy, material light design sensibility. A vital and timely new design philosophy that reveals how meaning emerges from designed encounters between people and things, explores ways to increase the quality and longevity of our relationships with objects, and the systems behind them, and ultimately, demonstrates why design can and must lead the transition to a sustainable future.

51-495 History and Future of Interaction Design

Intermittent: 9 units
The history of Interaction Design is far richer than what is commonly known among students and teachers, practicing designers and entrepreneurs. Understanding IxD's origins and evolution helps us realize the promises and possibly avoid some of the pitfalls of IxD's future. This course blends readings, lectures, discussions, and prototyping as a means for students to experience this history as if first-hand. Students become immersed in pragmatic yet mind-expanding examples of person-machine interactions and #8212; such as MEMEX, Musicolour, Hypertext, Dynabook, Fun Palace, Colloquy of Mobiles, Architecture Machine, THOUGHTSTICKER, Architrainer, and Hypercard. Through period articles and subsequent perspectives, students research a handful of historical innovationsand then prototype key concepts from that history, forefronting what has been lost in modern commercial implementations. This offers students a hands-on experience of the history of IxD. To explore IxDs future, students are invited to invent it and #8212; to prototype their individual future vision of interactive experiences. The course is especially suitable for students with interest or background in interaction design, computational design, responsive architecture, and interactive media.

51-496 Systems, Cybernetics, Conversation

Intermittent: 9 units
Across many design disciplinesarchitecture and computational design, media and interaction design, design of services and organizationsmethods for grappling with complex adaptive systems is now table stakes. Furthermore, design today demands profound, authentic attention to equity, human and non-human living systems, climate and environment, sustainability and ethics. Overall, designers must have skills to collaborate in cross-disciplinary teams. An encompassing framework for these disparate disciplines and domains of 21st-century design is the transdisciplinarity (or "antidisciplinarity") of Cybernetics. Cybernetics can be understood as the study of "systems with purpose", whether machines or living things, including their unpredictable interactions. Central to Cybernetics is conversation as a mechanism of design, inclusivity, participation, innovation, and the impetus to action. The course offers systems frameworks and models of conversation that are also relevant to Designing for the Internet of Things (48-675), Inquiry into Computation Design (48-727), and Design Studies: Systems (51-277). Class time balances readings, discussion panels, and guest conversations with executing assignments that involve systems modeling; creating conditions for designing that are participatory and inclusive; and prototyping in a range of media (installations, screen-based interactivity, physical prototypes, workshops, etc.) that offer responses to global wicked challenges.

51-498 Design Center: What If?

Intermittent: 6 units
WHAT IF? is a media, arts, and design-led exploration of speculation, conjecture, and storytelling. Using play and worldbuilding, we will investigate science fictional constructs, conjure alternative pasts and presents, voyage to the edge of the imaginable, and blur the borders between possible and impossible. How do you build a time machine, anyway?

51-499 Senior Independent Study

All Semesters
Proposal forms are available on the Design Intranet. Proposals must be approved by faculty before pre-registration.

51-504 Design Fusion: Patterns in Nature

Intermittent: 5 units
Natural patterns have fascinated humans for thousands of years. Explore the diversity of insect visual design, from super-sneaky camouflage to the loudest warning signals; learn why patterns occur in nature and how form and function intersect in insects. Use hands-on, up-close examination of museum specimens to study and illustrate your own original bio-inspired artwork. This course is offered through the Joseph Ballay Center for Design Fusion.This course is open to those with basic drawing proficiency and Photoshop skills.

51-505 Design Fusion: Bugs and Bioinspiration

Intermittent: 5 units
How do insects build complex and efficient mechanical structures that rival human technology? What is the basic insect toolkit, and how have beetles adapted it to create glowing light, fire detectors, explosive weaponry, and color-changing armor? Explore these questions and examine the worlds most remarkable bugs up close, with specimens from the Carnegie Museum of Natural History. This course is offered through the Joseph Ballay Center for Design Fusion. This course is open to those with basic drawing proficiency and Photoshop skills.

51-506 Design Fusion: Creative Concepting

Intermittent: 5 units
Explore what distinguishes good ideas from great ideas and develop skills for ideating, developing, and visualizing a compelling concept that resonates with clients - in an agency-like environment. This course is offered through the Joseph Ballay Center for Design Fusion. Students must have visual drawing and image-making skills with access to Adobe Creative Cloud (Photoshop, Acrobat, Illustrator, etc), Powerpoint or similar presentation-making software.

51-507 Design Fusion: Designing for Presence

Intermittent: 5 units
The discipline of design is motivated by a drive to make things better. It can be very difficult, however, to maintain a genuine engagement required to address the biggest challenges we face, when our personal, social, civic, economic and environmental anxieties take so much of our energy. How can we sustainably apply our creative problem solving when we regularly feel overwhelmed? Designing for Presence helps us nurture ourselves and our connections as part of our practice of improving the world. Through a combination of readings, seminar discussion, mindfulness practices and a collaborative project, we will simultaneously fortify ourselves, cultivate empathy toward others, and explore practical design interventions to a real issue affecting the local community.

51-508 Design Fusion: Designing Data

Intermittent: 5 units
Our modern lives are flooded with data. This course provides an introduction to designing with data for non data-scientists and uses a project-based approach to explore types, formats, sources, and the visual presentation of different types of data. Students will work with a variety of qualitative, quantitative and experimental data sources. While there are no prerequisites for the course, students should have a working knowledge of some form of software that can be used to analyze and visualize data, including (but not limited to), Excel, Adobe Creative Cloud (Illustrator, Photoshop, etc), Google sheets, Apple Numbers, Sketch, Miro, Figma, etc.

51-509 Design Fusion: Drawing Linguistics

Intermittent: 5 units
Whether you are drafting a business plan, building a home, designing an app, or commissioning a piece of art, the intent and clarity of an idea is reliant on the fidelity and form of how it is communicated. Written forms of communication can be misinterpreted; existing reference imagery can be too limiting; but drawing offers an opportunity to specify exact detail and reflect the creator's imagination to the nth degree- all that is needed are the skills to capture those details. This course will explore the ways we can synthesize, distill, and communicate the essence of an idea through drawing. Prior drawing experience is not required.

51-630 RE.Futuring Craft

Intermittent: 9 units
This course explores the role of craft objects in shaping material culture and material futures aiming to offer propositional and speculative concepts to future-cast craft objects within natural, societal political, economic, scientific, and technological systems. Students engage in project-based learning that simulates diverse future scenarios to critically analyze material trends and their impact on future hand-crafted product design.

51-646 Design for Aging

Intermittent: 5 units
The population is aging at a staggering rate. Though not the only factor, the last of the baby boomers (b. 1946-1964) are turning 60 this year (the oldest boomer turning 78). Similar aging statistics apply in the US and internationally. Implications for design are evident. Ignoring this segment of the population in the design decisions we make would not only be socially and physically detrimental; it would also overlook an enormous opportunity. In this course we will examine the broad scope of aging with an inclusive intent already established through the premise of universal design. This means challenging assumptions and stereotypes, recognizing the enormous diversity in how people age. Through readings, other media, guests, and direct hands-on experiences, we will understand and gain an appreciation for the range of changes that occur with aging, including physical and cognitive abilities, social and emotional wellbeing. While we will learn from other disciplines, the focus will be on implications for the design of products, communications, environments, and conditions for interactions in and with the world.

51-818 Diversity, Equity, Inclusion and Design

Intermittent: 12 units
In this course, students will explore Diversity, Equity, and Inclusion (DEI) issues as they relate to the School of Design to propose and possibly implement and initiate efforts to begin to address some of these issues. We will learn about the systems, structures, and tools for, by, and with Design at the intersection of DEI. Foundational lectures, discussions, and hands-on workshopscombined with a review and consolidation of precedent research and work supporting the definition and scope of DEI. Through a variety of group exercises, directed working sessions, guest lectures by subject matter experts, readings, case studies, and more, students will be guided through an intensive learning process. Students will work individually and collaboratively, including working with the full course cohort. We will ask questions such as: What do we mean by DEI? What are the opportunities and challenges within the design discipline and its pipelines? Within design pedagogy and practice? With designers and designing? What happens if we put DEI at the center of our work? How do we develop new postures and mindsets that place DEI at the forefront of the School of Design at Carnegie Mellon University?

School of Drama

Location: Purnell Center for the Arts, 221
www.drama.cmu.edu (http://www.drama.cmu.edu)

The School of Drama at Carnegie Mellon University is the oldest drama program in the country. CMU Drama offers rigorous, world-class classical training in theater while providing thorough preparation for contemporary media.

As a member of the Consortium of Conservatory Theater Training Programs, the school chooses students to participate in the program based on their potential ability. Every Drama student is treated as a member of a theatrical organization and must acquire experience in all phases of the dramatic arts. Students are also asked to broaden their knowledge through courses in the other colleges of the university. The undergraduate Drama program, which incorporates approximately 200 students, leads to a Bachelor of Fine Arts in Drama. The areas available are: Acting, Music Theater, Design, Production Technology and Management, Directing (admission on pause for fall 2024 and fall 2025), and Dramaturgy. The production of plays, a natural extension of demanding class work, is our lab, and constitutes one of the school's major activities. The choice of texts used is determined by the particular needs of current students. Each semester, 15 to 25 lab productions, directed by faculty, guest directors, and advanced students, are presented in our three theater spaces. The labs range from completely mounted, full-length dramatic and musical works to more simply produced directing projects and one-acts. The Drama program is rigorous and exacting, making demands on students that necessitate good health, a willingness to work and a commitment to professional discipline at all times. Because of full daytime class work and heavy production schedules, much production preparation takes place in the evening. Drama students, therefore, are advised to live in residence halls or in the immediate vicinity of the campus.

The information contained in this section is accurate as of July 2024 and is subject to change. Please contact the School of Drama at drama-relations@andrew.cmu.edu *with any questions.*

Programs in Drama

Acting and Musical Theater Program

The Acting and Musical Theater program is designed to prepare the student for immediate entry into the profession. It is a sequence-based training program with accumulative skills building upon each other over the course of four years. It is a conservatory training course, and the curriculum focuses primarily on the technique and craft of theater. At the same time it offers skills that are applicable to all media. Courses in acting, voice, speech, movement, and theater history are integral parts of the program at all four levels. In addition to studio classes, Acting majors are required to take a number of electives outside the School of Drama to expand their intellectual curiosity and worldview. All students must demonstrate a commitment to growth, show continued progress in their work and in the knowledge of their craft, and show a respect for professional standards in discipline, quality and ethics.The first year is a discovery year and provides an introduction to basic skills-working from self, learning to play objectives and actions and the beginning of character exploration. In the sophomore year these skills are solidified and deepened as more sophisticated, verbally complex material is introduced, through a focus on in-depth scene study, both contemporary and Shakespeare. In the junior year students continue to develop their craft by investigating a variety of styles. Skills are now tested and strengthened through public performance. The senior year provides a bridge from training to the professional world and offers the opportunity to appear on the School of Drama's main stage. At the end of the senior year, students are introduced to the profession through Showcase performances in New York City and Los Angeles.The students in the Music Theater program share the training philosophy and much of the same curriculum as the acting program. In addition, they take courses particular to the demands of Music Theater. These include private voice along with training in a variety of dance techniques (Ballet, Jazz, Tap, Dunham Technique and Broadway Styles) and music theater styles and skills.

Directing Program (admission on pause for fall 2024 and fall 2025)

The John Wells Directing Program promotes creativity, intellectual curiosity, critical thinking, a broad and well-rounded understanding of the theater and leadership ability. It provides a detailed exploration of the technique of directing for stage and for camera. The curriculum is designed for those serious about the art of directing and intending to pursue a career in theater, film or television.

Course work in scenic design, lighting, media, and costume design develops the students' visual sophistication as well as an understanding of how these elements combine in practical production situations to create new worlds. Stage management skills are studied and practiced. Theater history, criticism, playwriting, new play development and theater management classes introduce the student to the wide range of knowledge necessary for directing. Participation in acting classes develop a deep understanding of the actor’s journey as well as the communication skills necessary for collaboration. There are many avenues open for practical application: scene work in class, a short film written and directed by students, studio projects and even participating in choreography events. The broad scope of the directing curriculum encourages the director's interaction with all the theatrical disciplines. Collaboration in all forms, so necessary to the art, is the goal.

Design Area

Over the first three semesters, Design students are expected to develop artistic ability in the conception and execution of scene, lighting, sound and costume design for plays of all periods under varying theatrical conditions. All undergraduate students begin with the development of visual and written communication skills. These first three semesters immerse the student in a range of collaborative and individual studies: scenery, costume, sound and lighting design fundamentals; dramatic structure and interpretation; manual and computer-based drafting; perspective and figure drawing, fundamentals of directing; production management and preparation, history of art and history of architecture and décor. Freshmen in design receive instruction in drawing and painting, three-dimensional techniques, and in the application of basic design principles through courses in drawing and design. Sophomores learn to apply design principles to the theater through research, play analysis, and studies in the fundamentals of scene, lighting, sound and costume design. The last five semesters focus the student's skills within their chosen program of concentration: Costume, Sound, Lighting, Scenic or Video and Media Design. Juniors and Seniors take specialized courses in areas of stage design and are expected to head studio and main-stage production crews. Design assignments cover various styles and periods and include the preparation of models, renderings, and working drawings, lighting storyboards, and light plots. As part of the degree work, juniors may design sets, lights, sound or costumes for a production in the Studio Theater and seniors may design sets, lights, sound or costumes for a Master's thesis show or a main-stage production. Designing for lab productions, both those that are highly resourced and those that are moderately resourced, requires a variety of creative approaches, preparing designers for a variety of real-world situations.

Production Technology and Management (PTM) Area

The Production Technology and Management Area develops the technologists and managers of the future with an intensive curriculum designed to synthesize academic development and production experience. The curriculum focuses on the production requirements of live performance, in the form of traditional theatrical presentation, while also providing exposure to television, film and emerging technology-based art forms. Integrated in a world-class research university environment, the School of Drama is uniquely positioned to contribute to the advancement of the collaborative arts. The goal of the three PTM areas is to prepare today's students to become tomorrow's leading professionals in the entertainment industry.

All undergraduate students begin with the development of visual and written communication skills. The first three semesters immerse the student in a range of collaborative and individual studies: scenery, costume, sound and lighting design fundamentals; dramatic structure and interpretation; manual and computer-based drafting; perspective and figure drawing, fundamentals of directing; production management and preparation, history of art and history of architecture and décor. The last five semesters focus the student's skills within their chosen program of concentration: Technical Direction, Stage & Production Management, or Production Technology.

Technical Direction students are offered classes in: material applications, metal working techniques, structural design, scenic crafts, fabrication design and detailing, machinery design, rigging techniques, electronic design fundamentals, automation system technology, technical management and production management. Technical Directors may take a single semester internship at an approved regional or commercial producing organization in lieu of one semester of study. Student-selected elective courses outside the School of Drama provide balance and breadth to the professional undergraduate education offered in the Technical Direction program of study.

Stage and Production Management students are offered classes in: an extensive study of stage management and production management, theater management, leadership, problem solving and business communications, in addition to classes in resource management in all technical areas. Production assignments supplement classroom learning and development throughout the program. Student-selected elective courses outside the School of Drama provide balance and breadth to the professional undergraduate education offered in the Stage & Production Management program of study.

Production Technology students are offered a variety of classes in: scenic fabrication and technology, lighting technology, audio technology, show networking, technical, production, theater and stage management and design courses within one or more design discipline. Production responsibilities for Production Technology students may include roles as Lighting Managers, Technicians and Programmers, Audio Engineers, Mixers and Technicians, Video Engineers and Technicians, Scenic Automation Technicians and Managers and Network Integrators. Student-selected elective courses outside the School of Drama provide balance and breadth to the professional undergraduate education offered in the Production Technology program of study.

Dramaturgy Program

The dramaturgy curriculum provides students with a strong background in theatrical practice, dramatic literature, and humanities. A core course of study focusing on building the skills for production dramaturgy is augmented by an English minor along with directed electives in history, foreign languages, and other non-drama courses to build a firm foundation in both theater and the liberal arts.
Students in the dramaturgy program also cultivate their intellectual prowess, analytical skills, and artistic passions through integral involvement in the School of Drama's productions. Dramaturgy students work with directors, playwrights, designers, managers, and actors in the conception and execution of productions, bringing their knowledge of theater history and dramatic structure, their skills in script analysis and contextual research, and their capacity to engage in collaborative conversation into the rehearsal room. These skills also serve dramaturgy students as they practice the art of audience engagement.
The Dramaturgy program specializes in new play development, production support, critical writing, audience engagement, season planning, and artistic leadership. The wide ranging curriculum makes it an excellent program of study for students interested in theater history and theory, playwriting, and cultural studies. Alumni from the dramaturgy program have built careers not only in theater but also in film and television as well as in arts management, in literary and casting agencies, and in education.

Theater Studies

The Theater Studies program offers students from any of the School's conservatory areas of specialized study the opportunity to continue developing their theater related skills while expanding their interests to other artistic and academic areas. This program will only be available to Drama students who have completed their sophomore year in the School of Drama (ie: two years of conservatory training). Students are required to write a proposal outlining their interests in the Theater Studies program, and the proposal must be approved by the Head of the School of Drama.

The goal of the Theater Studies program is to enable students to explore the diverse opportunities for which conservatory drama training can be a basis, and to examine the possibility of post graduate education in a new program of specialization after obtaining a BFA in Drama. As the intent of the Theater Studies program is to broaden your experiences, a semester studying abroad or participating in a recommended internship is required for one semester, either in the fall or spring. Individualized courses of study are established for each student in consultation with an appropriate faculty advisor.

Curriculum

The School of Drama curriculum is continuously reviewed and modified in an effort to provide the best conservatory experience for undergraduate students in the School of Drama. The following curriculum is subject to change. Not all requirements are listed, and units are often variable within each Area based on performances, production assignments, and individual projects.

Acting Program

First Year

Fall		Units
54-101	Acting I	10
54-011	Introduction to Alexander Technique (mini 1)	1
54-103	Speech I	4
54-105	Voice for the Stage I	5
54-107	Movement I	4
54-110	Text for Actors (mini 2, section A)	2
54-177	Foundations of Drama I (section A)	6
99-101	Core@CMU	3
54-362	Anti-Racist & Equitable Practices in Theater	6
76-101	Interpretation and Argument	9
		50

Spring		Units
54-102	Acting I	10
54-104	Speech I	6
54-106	Voice for the Stage I	5
54-108	Movement I	4
54-159	Production Practicum	6
xx-xxx	Global Persepctives	9
xx-xxx	Non-Drama elective	6-9
54-285	Alexander Technique Tutorials	1.5
		47.5-50.5

Sophomore Year

Fall		Units
54-201	Acting II	12
54-203	Voice and Speech II	4
54-207	Movement II	4
54-211	Actor Dance II	3
54-281	Foundations of Drama II *	6
54-213	Singing for Actors II (Optional)	3
62-314	The Art of Personal Finance	6
xx-xxx	Non-Drama Elective	6-9
54-209	Voice and Speech II: Practicums	3
54-285	Alexander Technique Tutorials	1.5
xx-xxx	Global Perspectives (if not taken)	
		48.5-51.5

Spring		Units
54-202	Acting II	12
54-204	Voice and Speech II	4
54-208	Movement II	3
54-212	Actor Dance II	3
54-242	Improvisation	2
xx-xxx	Non-Drama Elective	6-9
54-214	Singing for Actors II (Optional)	3
54-159	Production Practicum	6
54-285	Alexander Technique Tutorials (optional)	1.5
54-209	Voice and Speech II: Practicums (2 minis)	3
54-381	Special Topics: Feminist Theatre	6
or 54-336	Musical Theater History	
		49.5-52.5

Junior Year

Fall		Units
54-301	Acting III (mini-1 + mini-2)	10
54-305	Voice for the Stage III	5
54-307	Movement III	5
54-309	Speech III	4
54-325	Actor Dance III	2
xx-xxx	Non-Drama Elective	6-9
54-317	Singing for Actors III (Optional)	2
54-327	Auditioning for TV/Film (Optional)	2
54-285	Alexander Technique Tutorials (Optional)	1.5
54-311	Rehearsal and Performance III (if assigned)	16
		53.5-56.5

Spring		Units
54-302	Acting III (mini-3 & mini-4)	10
54-310	Dialects and Accents	6
54-306	Voice for the Stage III	5
54-308	Movement III	5
54-312	Rehearsal and Performance III	16
54-326	Actor Dance III	2
xx-xxx	Non-Drama Elective	6-9
54-318	Singing for Actors III (Optional)	2
54-335	Auditioning for the Stage (optional)	2
54-285	Alexander Technique Tutorials (optional)	1.5
		55.5-58.5

Senior Year

Fall		Units
54-285	Alexander Technique Tutorials (Optional)	1.5
54-407	Movement IV	6
54-413	Showcase (mini 2)	6
54-493	Business of Acting & The Practice	4
54-411	Rehearsal and Performance IV	16
54-519	Acting for the Camera	6
xx-xxx	Non-Drama Elective	6-9
54-403	Actor as Artist	6
		51.5-54.5

Spring		Units
54-285	Alexander Technique Tutorials (Optional)	1.5
54-412	Rehearsal and Performance IV	16
54-414	Showcase	9
54-520	Acting for the Camera	8
54-438	Acting IV-Improv (mini 4)	3
xx-xxx	Non-Drama Elective	6-9
		43.5-46.5

NON-DRAMA ELECTIVES:

Actors take a minimum of four Non-Drama Electives, 6-9 units each.

Music Theater Program

First Year

Fall		Units
54-101	Acting I	10
54-103	Speech I	4
54-105	Voice for the Stage I	5
54-107	Movement I	4
54-110	Text for Actors (mini-2, section B)	2
54-123	Dance Technique I: Physical Mechanics and Anatomy	5
54-125	Music Skills I	4
54-500	Voice Lab	5
99-101	Core@CMU	3
54-362	Anti-Racist & Equitable Practices in Theater	6
54-011	Introduction to Alexander Technique (mini-1)	1
		49

Spring		Units
54-102	Acting I	10
54-104	Speech I	6
54-106	Voice for the Stage I	5
54-108	Movement I	4
54-124	Dance I: Applying Dance Technique	5
54-126	Music Skills II	4
54-159	Production Practicum	6
54-500	Voice Lab	5
54-177	Foundations of Drama I	6
76-101	Interpretation and Argument	9
		60

Sophomore Year

Fall		Units
54-201	Acting II	12
54-203	Voice and Speech II	4
54-205	Dance II: Pillars to Build Dance Technique	3
54-207	Movement II	4
54-217	Jazz II	2
54-219	Special Topics: Music Theater History and Repertoire	6
54-223	Tap II - Rhythmic Technique/Foundational to Complex	2
54-500	Voice Lab	5
54-209	Voice and Speech II: Practicums	3
54-285	Alexander Technique Tutorials (optional)	1.5
62-314	The Art of Personal Finance (mini)**	6
xx-xxx	Global Perspectives	9
		57.5

Spring		Units
54-202	Acting II	12
54-204	Voice and Speech II	4
54-206	Dance II: Pillars to Build Dance Technique	3
54-208	Movement II	3
54-218	Jazz II	2
54-224	Tap II: Rhythmic Technique/Foundational to Complex	2
54-220	Acting A Song	4
54-159	Production Practicum	6
54-281	Foundations of Drama II	6
54-500	Voice Lab	5
54-209	Voice and Speech II: Practicums	3
54-285	Alexander Technique Tutorials (optional)	1.5
		51.5

Junior Year

Fall		Units
54-301	Acting III (mini-1 & mini-2)	10
54-305	Voice for the Stage III	5

54-309	Speech III	4
54-313	Dance III: Expand the Dynamics of Dance Technique	3
54-315	Jazz III	2
54-285	Alexander Technique Tutorials (Optional)	1.5
54-319	Cabaret	6
54-323	Tap III - Expand Percussive Rhythms	2
54-500	Voice Lab	5
54-311	Rehearsal and Performance III	16
54-327	Auditioning for TV/Film (optional)	2
		56.5

Spring		Units
54-302	Acting III (mini-3 & mini-4)	10
54-306	Voice for the Stage III	5
54-310	Dialects and Accents	6
54-312	Rehearsal and Performance III	16
54-314	Dance III: Expand Dynamic of Dance Technique	3
54-316	Jazz III	2
54-324	Tap III: Expand Percussive Rhythms	2
54-500	Voice Lab	5
54-374	Musical Theater Audition	5
54-335	Auditioning for the Stage (optional)	2
54-285	Alexander Technique Tutorials (optional)	1.5
		57.5

Senior Year

Fall		Units
54-285	Alexander Technique Tutorials (Optional)	1.5
54-413	Showcase (mini 2)	6
54-418	Songs for Showcase (mini 2)	2
54-415	Broadway Dance Styles	5
54-493	Business of Acting & The Practice	4
54-403	Actor as Artist	6
54-500	Voice Lab	5
54-519	Acting for the Camera	6
54-411	Rehearsal and Performance IV	16
		51.5

Spring		Units
54-285	Alexander Technique Tutorials (Optional)	1.5
54-412	Rehearsal and Performance IV	16
54-438	Acting IV-Improv (mini 4)	3
54-414	Showcase	9
54-416	Broadway Styles	5
54-500	Voice Lab /Senior Coaching	5
54-520	Acting for the Camera	8
54-418	Songs for Showcase	2
		49.5

** Music Theater students are required to take an approved Scientific and Quantitative Reasoning elective. Students usually take 62-314 The Art of Personal Finance to fulfill this requirement.

Design Area

First Year

Fall		Units
54-151	Stagecraft (combination of minis)	13
54-157	Production Science	6
54-169	Studiocraft 1	13
54-171	Basic Design 1	6
99-101	Core@CMU	3
54-362	Anti-Racist & Equitable Practices in Theater	6
or 54-177	Foundations of Drama I	
76-101	Interpretation and Argument	9
54-159	Production Practicum (if not in spring)	6
		62

Spring		Units
54-152	Stagecraft (combination of minis)	13
54-158	Production Planning	6
54-170	Studiocraft 2	8
54-172	Basic Design 2	6
54-177	Foundations of Drama I	6
or 54-362	Anti-Racist & Equitable Practices in Theater	
xx-xxx	Non-Drama Elective (optional)	6-9
xx-xxx	Global Perspectives	9
54-159	Production Practicum (if not in fall)	6
		60-63

Sophomore Year

Fall - ALL DESIGN		Units
54-281	Foundations of Drama II (section B/or in the spring) *	6
xx-xxx	Non-Drama Elective	6-9
54-284	Fundamentals of Directing	6
54-231	Design for the Stage	6
54-232	Design for the Stage: Lighting	4
54-249	Stagecraft II	14
54-271	Technical Management	6
		48-51

Spring - ALL DESIGN		Units
54-xxx	Production Preparation	varies
54-281	Foundations of Drama II (if not in fall) *	6
xx-xxx	Non-Drama Elective	6-9
54-xxx	Vectorworks (if required by your area)	6

Spring - SOUND DESIGN (consult with advisor)		Units
54-166	Introduction to Sound Design for Theatre	6
54-666	Production Audio	6
54-117	Design Collaboration Project (mini)	3
54-548	Sound Forum	1

Spring - COSTUME DESIGN (consult with advisor)		Units
54-162	Introduction to Costume Design	6
54-230	Make-Up for Designers	6
54-346	Introduction to Costume Construction	6
54-447	Figure Drawing (or in a future semester)	3
54-117	Design Collaboration Project (mini)	3
54-320	Costume Forum	1

Spring - SCENIC DESIGN (consult with advisor)		Units
54-250	Introduction to Scenic Design	6
54-386	Scenic Design Skills: 3D Model Making (mini)	4
54-392	Scenic Design Skills: 2D Drawing and Rendering (mini)	4
54-350	Scenic Design Forum	1
54-117	Design Collaboration Project	3

Spring - LIGHTING DESIGN (consult with advisor)		Units
54-252	Introduction to Lighting Design	6

54-368	Introduction to Lighting Management	6
54-287	Introduction to Lighting Design Skills	3
54-117	Design Collaboration Project (mini)	3
54-337	Introduction to Lighting Technology	6
54-384	Lighting Design Forum	1

Spring - VIDEO & MEDIA DESIGN (consult with advisor)		Units
54-297	VMD Systems Studio	9
60-120	Foundations: Digital Media (This is not a non-drama elective)	10

Junior Year

Fall - ALL DESIGN		Units
54-xxx	Production Preparation	varies
54-381	Special Topics: Feminist Theatre (if needed)	6

Fall - SOUND DESIGN (consult with advisor)		Units
54-267	Conceptual Sound Design	9
54-389	Composition for Theatrical Sound Design 1	9
54-505	Ear Training	1
54-548	Sound Forum	1
57-152	Harmony I	9

Fall - COSTUME DESIGN (consult with advisor)		Units
54-245	Who Wore What: When, Where, and Why	6
54-341	Fundamentals of Costume Design	9
54-373	Draping Fundamentals (mini-1)	3
54-486	Understanding Textiles (mini-2)	3
54-511	Millinery I (or in senior year/every other year)	9
54-539	Fabric Dyeing I (optional, every other year)	9
54-473	Drawing for Theatrical Designers	9
54-441	Costume Design for Dance (mini)	5
54-320	Costume Forum	1

Fall - SCENIC DESIGN (consult with advisor)		Units
54-237	Scenic Painting I	6
54-331	Scenic Design: Explorations	9
54-473	Drawing for Theatrical Designers (or in future semester)	9
54-383	Introduction to Digital Media	9
54-350	Scenic Design Forum	1
xx-xxx	Approved Art History course (or in spring)	6-9

Fall - LIGHTING DESIGN (consult with advisor)		Units
54-524	Dance Lighting Design 2 (mini-2)	3
54-351	Theatrical Lighting Design	9
54-367	Lighting Design Skills	6
54-469	Dance Lighting Design 1 (mini-1)	3
54-525	Entertainment Lighting Programming	9
54-396	Theatrical Lighting Management	6
54-384	Lighting Design Forum	1
54-380	Music Reading for Production	3

Fall - VIDEO & MEDIA DESIGN (consult with advisor)		Units
54-399	Decoding Media	9
xx-xxx	VMD Interdepartmental Course	9
54-xxx	Other Design "Co-option" course (optional)	varies
54-476	Media Creation Studio (if offered)	6
60-110	Foundations: Time-Based Media	10

Spring - ALL DESIGN		Units
54-xxx	Production Preparation	varies
54-381	Special Topics: Feminist Theatre (if needed)	6
xx-xxx	Non-Drama Elective	6-9

Spring - SOUND DESIGN (consult with advisor)		Units
54-390	Composition for Theatrical Sound Design 2	9
54-505	Ear Training	1
54-328	Advanced Digital Sound Design Skills	9
54-548	Sound Forum	1

Spring - COSTUME DESIGN (consult with advisor)		Units
54-442	Costume Design for the Classics	5
54-450	Painting for the Theatrical Designer (every other year) or	9
or 54-470	Costume Rendering	
54-xxx	Costume Crafts Mini (varies each semester, optional)	6
54-444	Advanced Designer Draping (optional)	6
54-246	Who Wore What: When, Where, Why II	6
54-379	Captured Storytelling (optional)	7
54-516	Fabric Painting (every other year, optional)	9
54-320	Costume Forum	1
54-336	Musical Theater History	6

Spring - SCENIC DESIGN (consult with advisor)		Units
54-238	Scenic Painting II	6
54-332	Scenic Design: Boot Camp (mini-3 & mini-4)	9
54-450	Painting for the Theatrical Designer (or approved substitute)	9
54-350	Scenic Design Forum	1
xx-xxx	Approved Art History course (if not taken)	6-9

Spring - LIGHTING DESIGN (consult with advisor)		Units
54-352	Musical and Opera Lighting Design	9
54-565	Dance/Light (mini-3)	3
54-384	Lighting Design Forum	1

Spring - VIDEO & MEDIA DESIGN (consult with advisor)		Units
54-400	Staging Media- Immersive Edition	9
xx-xxx	VMD Approved Interdepartmental class	9
54-xxx	Other Design "Co-Option" course (optional)	6

Senior Year

Fall - ALL DESIGN		Units
54-xxx	Production Preparation	varies
54-381	Special Topics: Feminist Theatre (if needed)	6

Fall - SOUND DESIGN (consult with advisor)		Units
54-268	Collaborations in Organized Sound	3
54-505	Ear Training	1
54-398	Special Topics in Sound Design	9

Fall - COSTUME DESIGN (consult with advisor)		Units
54-447	Figure Drawing	3
54-511	Millinery I (offered every other year) or 54-539 Fabric Dyeing (if offered, optional)	9
54-xxx	Costume Crafts Mini (varies each semester, optional)	
54-320	Costume Forum	1
54-498	Expanded Theater (or Scenography or CD for TV & Film in the spring)	6
54-450	Painting for the Theatrical Designer (if offered)	9
xx-xxx	Approved Art History course (if not taken)	6-9

Fall - SCENIC DESIGN (consult with advisor)		Units
54-473	Drawing for Theatrical Designers or approved drawing sub (if not taken)	9
54-432	Design for Spaces (mini-1 & mini-2)	4.5 & 4.5
54-350	Scenic Design Forum	1
54-498	Expanded Theater	6
54-451	Scenic Design Packet (mini-1)	4

Fall - LIGHTING DESIGN (consult with advisor)		Units
54-524	Dance Lighting Design 2 (mini-2) (may be repeated)	3
54-491	Concert Lighting Design	9
54-525	Entertainment Lighting Programming (Optional)	9
54-384	Lighting Design Forum	1

Fall - VIDEO & MEDIA DESIGN (consult with advisor)		Units
54-xxx	Other Design "Co-Option" course	varies
54-521	Video Media Design Senior Thesis (or approved Advanced VMD course)	Var.
54-461	Experimental Capture	12
54-498	Expanded Theater	6

Spring - ALL DESIGN		Units
54-381	Special Topics: Feminist Theatre (if needed)	6
xx-xxx	Non-Drama Elective	6-9
54-361	Production Preparation	Var.

Spring - SOUND DESIGN (consult with advisor)		Units
54-372	Theatre for the Ear	6
54-397	Sound Design For Interactive Environments	9
54-505	Ear Training	1
54-548	Sound Forum	1

Spring - COSTUME DESIGN (consult with advisor)		Units
54-450	Painting for the Theatrical Designer (every other year) or	9
or 54-470	Costume Rendering	
54-xxx	Costume Crafts Mini (varies each semester)	
54-342	Costume Design for TV and Film or Scenography (if ET not taken in fall)	7
54-320	Costume Forum	1
xx-xxx	Approved Art History course (if not taken)	6-9

Spring - SCENIC DESIGN (consult with advisor)		Units
54-450	Painting for the Theatrical Designer (or approved sub in Arch or Art, if not taken)	9
54-350	Scenic Design Forum	1
54-431	Scenography	9

Spring - LIGHTING DESIGN (consult with advisor)		Units
54-452	Architectural Lighting Design	4.5
54-565	Dance/Light (may be repeated)	3
54-384	Lighting Design Forum	1

Spring - VIDEO & MEDIA DESIGN (consult with advisor)		Units
54-xxx	Other Design "Co-Option" course (optional)	Var.
54-521	Video Media Design Senior Thesis (or Advanced VMD course)	Var.
54-400	Staging Media- Immersive Edition or VMD: Mediated Reality (if offered)	9

NON-DRAMA ELECTIVES:

Designers take a minimum of five Non-Drama Electives, 6-9 units each.

Notes:

** All Designers are required to complete Special Topics in Drama: History, Literature and Criticism. It may be taken at any time after Foundations II has been completed.

Directing Program (Admissions on pause for fall 2024 and fall 2025)

First Year

Fall		Units
54-121	Directing I: A Director's Mindset	9
54-167	Acting for Directors I	10
54-107	Movement I (section C)	4
54-109	Dramaturgy 1: Approaches to Text	9
54-110	Text for Actors (mini-2, section C)	2
99-101	Core@CMU	3
54-517	Directors Common Hour	1
54-159	Production Practicum	6
54-362	Anti-Racist & Equitable Practices in Theater (section A)	6
		50

Spring		Units
54-122	Directing I: A Director's Preparation	9
54-168	Acting for Directors I	10
54-159	Production Practicum	6
54-184	Dramaturgy 2: Introduction to Production Dramaturgy	9
54-177	Foundations of Drama I	6
76-101	Interpretation and Argument or (76106 & 76108)	9
		49

Sophomore Year

Fall		Units
54-233	Acting For Directors II	12
54-221	Directing II: In the Studio	9
54-281	Foundations of Drama II (or in the spring)	6
54-271	Technical Management (Optional)	6
62-314	The Art of Personal Finance (mini)	6
76-270	Writing for the Professions (section J)	9
54-xxx	Directing: Production II (by assignment)	
		48

Spring		Units
54-234	Acting For Directors II	12
54-222	Directing II: In The Room	9
54-330	Introduction to Stage Management	6
54-117	Design Collaboration Project (mini)	3
xx-xxx	Non-Drama Elective (Global Perspective if not completed)	9
54-xxx	Directing: Production II (by assignment)	6
54-381	Special Topics: Feminist Theatre (or in a future semester)	6
		51

Junior Year

Fall		Units
54-322	Directing III: INTRODUCTION TO TV & FILM DIRECTING	9
85-102	Introduction to Psychology (section F or one that fits)	9
54-381	Special Topics: Feminist Theatre or 54-336 (if needed)	6
xx-xxx	Non-drama elective	6-9
54-247	Dramaturgy 6: In Company	9

54-331	Scenic Design: Explorations	9
		48-51

Spring - NYC TEPPER INTERNSHIP SEMESTER	
Tepper Semester courses (register with Syracuse)	36

Senior Year

Fall		Units
54-422	Directing IV: Next Steps	9
54-247	Dramaturgy 6: In Company (if not taken)	9
xx-xxx	Non-Drama Elective	6-9
54-498	Expanded Theater	6
54-381	Special Topics: Feminist Theatre (if needed)	6
54-331	Scenic Design: Explorations (if not taken)	9
54-xxx	Directing: Production IV (Capstone prep)	6-16
		51-64

Spring		Units
54-422	Directing IV: Next Steps	9
54-458	Directing: Production IV (Capstone) **	Var.
xx-xxx	Non-Drama Elective	6-9
54-381	Special Topics: Feminist Theatre (if needed)	6
54-431	Scenography	9
54-xxx	Directing for TV & Film 2 (or approved film elective)	9
		39-43

NON-DRAMA ELECTIVES:

Directors take a minimum of four Non-Drama Electives, 6-9 units each.

Notes:

** One semester of Directing Production IV: Senior Thesis Play is required. Second semester is Optional.

Production Technology and Management (PTM) Area

First Year

Fall		Units
54-151	Stagecraft (combination of minis)	13
54-157	Production Science	6
54-169	Studiocraft 1	13
54-171	Basic Design 1	6
99-101	Core@CMU	3
54-362	Anti-Racist & Equitable Practices in Theater	6
or 54-177	Foundations of Drama I	
76-101	Interpretation and Argument	9
54-159	Production Practicum	6
		62

Spring		Units
54-152	Stagecraft (combination of minis)	13
54-170	Studiocraft 2	8
54-158	Production Planning	6
54-172	Basic Design 2	6
54-177	Foundations of Drama I	6
or 54-362	Anti-Racist & Equitable Practices in Theater	
xx-xxx	Global Perspectives	9
		48

Sophomore Year

Fall		Units
54-231	Design for the Stage	6
54-232	Design for the Stage: Lighting	4
54-271	Technical Management	6
54-249	Stagecraft II	14
54-281	Foundations of Drama II (section B) (or in spring) **	6
54-284	Fundamentals of Directing	6
xx-xxx	Non-Drama Elective	6-9
		48-51

Spring - ALL PTM		Units
54-xxx	Production Preparation (64 units total for PT over 5 semesters 8, 12, 12, 16, 16) (88 units total for TD over 5 semesters 12, 18, 18, 20, 20)	varies
54-334	Production Resource Management	6
54-281	Foundations of Drama II (if not in fall)	6
xx-xxx	Non-Drama Elective	6-9

Spring - PTM TECHNICAL DIRECTION		Units
54-264	Welding	4
54-265	Advanced Fabrication 1	6
54-330	Introduction to Stage Management	6
54-272	Scenic Fabrication and Installation (mini-3)	3
54-286	Stage Rigging Concepts (mini-4)	3
54-xxx	Vectorworks	6

Spring - PTM STAGE & PRODUCTION MANAGEMENT (SPM)		Units
54-666	Production Audio	6
54-330	Introduction to Stage Management	6
54-286	Stage Rigging Concepts (mini-4)	3

Junior Year

Fall - ALL PTM		Units
54-xxx	Production Preparation (64 units total for PT over 5 semesters 8, 12, 12, 16, 16) (88 units total for TD over 5 semesters 12, 18, 18, 20, 20)	varies
54-273	Technical Direction I	6
54-381	Special Topics: Feminist Theatre ***	6
xx-xxx	Non-Drama Elective	6-9

Fall - PTM TECHNICAL DIRECTION		Units
54-353	Structural Design I ~	9
or 54-366	Physics of Stage Machinery	
54-295	Advanced Fabrication II	6

Fall - PTM SPM		Units
54-266	Stage Management: Cue Lab	4
54-339	Stage Management Seminar	3
54-380	Music Reading for Production	3
54-455	Production Data Manipulation	9

Spring - ALL PTM		Units
54-381	Special Topics: Feminist Theatre (if needed) ***	6
54-xxx	Production Prep (64 units total for PT over 5 semesters 8, 12, 12, 16, 16) (88 units total for TD over 5 semesters 12, 18, 18, 20, 20)	varies
xx-xxx	Non-Drama Elective	6-9
54-355	30 Hour OSHA (if offered)	2

Spring - PTM TECHNICAL DIRECTION		Units
54-354	Structural Design II ~	9
or 54-365	Machine Design I	
54-378	Technical Direction II	6

Spring - PTM SPM		Units
54-339	Stage Management Seminar	3
54-453	Production Management Workshop	3

54-368	Introduction to Lighting Management	6
54-454	Advanced SM: Management Styles	6
54-270	Adv Topics in SM: Communication	6

Senior Year

Fall - ALL PTM		Units
54-xxx	Production Preparation (64 units for PT over 5 semesters 8, 12, 12, 16, 16) (88 units total for TD over 5 semesters 12, 18, 18, 20, 20)	varies
54-381	Special Topics: Feminist Theatre*** (if needed)	6
xx-xxx	Non-Drama Elective	6-9
54-333	Production Personnel Management or 54-455 PDM (if needed)	6

Fall - PTM TECHNICAL DIRECTION		Units
54-477	Technical Direction III	6
54-353	Structural Design I ~	9
or 54-366	Physics of Stage Machinery	
54-376	Entertainment Rigging (optional)	3
54-279	Embedded Electronics (if needed)	3

Fall - PTM SPM		Units
54-339	Stage Management Seminar	3
54-453	Production Management Workshop	3
54-454	Advanced SM: Management Styles	6

Spring - ALL PTM		Units
54-xxx	Production Preparation (64 units total for PT over 5 semesters 8, 12, 12, 16, 16) (88 units total for TD over 5 semesters 12, 18, 18, 20, 20))	varies
54-381	Special Topics: Feminist Theatre*** (if needed)	6
54-355	30 Hour OSHA (if not taken)	2
54-468	Theater Management (if not taken)	6

Spring - PTM TECHNICAL DIRECTION		Units
54-354	Structural Design II	9
or 54-365	Machine Design I	
54-480	Technical Direction IV	6

Spring - PTM SPM		Units
54-339	Stage Management Seminar	3
54-453	Production Management Workshop	3
54-475	Advanced Topics in Stage Management: Cross-Boundaries	6

NON-DRAMA ELECTIVES:
PTM students take a minimum of five Non-Drama Electives, 6-9 units each.
SPM Students must complete 4 Directed Drama Electives.

Notes:

** Foundations of Drama II will be taken only one semester in the sophomore year. Sophomore PTM students will be required to take an approved Humanities and Social Sciences (H&SS) elective in the Deitrich College during the semester they are not taking Foundations of Drama II.

*** All PTM students are required to complete Special Topics in Drama: History, Literature and Criticism. It may be taken at any time after Foundations II has been completed.

~ Classes offered in alternating years.

Production Technology (program within PTM)

Fall		Units
54-151	Stagecraft (combination of minis)	6/8
54-157	Production Science	6
54-169	Studiocraft 1	13
54-171	Basic Design 1	6
99-101	Core@CMU	3
54-362	Anti-Racist & Equitable Practices in Theater or 54-177 Foundations of Drama I	6
76-101	Interpretation and Argument	9
54-159	Production Practicum (if not taken in spring)	6
		49-55

Spring		Units
54-152	Stagecraft (combination of minis)	6/8
54-170	Studiocraft 2	8
54-158	Production Planning	6
54-172	Basic Design 2	6
54-177	Foundations of Drama I or 54-362 Anti-Racist and Equitable Practices in Theater	6
xx-xxx	Global Perspectives	9
54-159	Production Practicum (if not taken in fall)	6
		41-47

Fall		Units
54-231	Design for the Stage	6
54-232	Design for the Stage: Lighting	4
54-271	Technical Management	6
54-249	Stagecraft II	14
54-281	Foundations of Drama II **	6
54-284	Fundamentals of Directing	6
xx-xxx	Non-Drama Elective	6-9
		48-51

Production Technology-discuss timeline with advisor		Units
54-xxx	Production Preparation (5 semesters: 8, 12, 12, 16, 16 units)	64
54-272	Scenic Fabrication and Installation (mini-3)	3
54-330	Introduction to Stage Management	6
54-468	Theater Management	6
54-368	Introduction to Lighting Management (and 54-369)	6
or 54-666	Production Audio	
54-252	Introduction to Lighting Design and 54-287	6
or 54-166	Introduction to Sound Design for Theatre	
or 54-297	VMD Systems Studio	
54-xxx	Vectorworks	
54-509	Theatrical Sound System Design 2 or 54-527	9
54-117	Design Collaboration Project	3
54-287	Introduction to Lighting Design Skills	3
54-337	Introduction to Lighting Technology	6
54-286	Stage Rigging Concepts (mini-4)	3
54-666	Production Audio (section B)	4
54-166	Introduction to Sound Design for Theatre	6
54-455	Production Data Manipulation	9
54-359	Introduction to Show Networking	3
54-279	Embedded Electronics	3
54-396	Theatrical Lighting Management	6
54-525	Entertainment Lighting Programming	9
54-xxx	Advanced Technology Elective	6-9

Dramaturgy Program

First Year

Fall		Units
54-109	Dramaturgy 1: Approaches to Text	9
54-177	Foundations of Drama I	6
54-200	Dramaturgy Forum	1

76-101	Interpretation and Argument or 76108 (mini) and 76106 (mini)	9
82-xxx	Foreign Language *	9-12
99-101	Core@CMU	3
54-159	Production Practicum (Run Crew)	6
54-284	Fundamentals of Directing	6
		49-52

Spring		Units
54-159	Production Practicum (Run Crew)	6
54-184	Dramaturgy 2: Introduction to Production Dramaturgy	9
82-xxx	Foreign Language *	9-12
54-281	Foundations of Drama II	6
54-117	Design Collaboration Project (mini-4)	3
54-200	Dramaturgy Forum	1
54-362	Anti-Racist & Equitable Practices in Theater	6
xx-xxx	Non-Dramaturgy Elective	6-9
		46-52

Sophomore Year

Fall		Units
54-299	Dramaturgy Production:Assistant (or in spring)	9
54-200	Dramaturgy Forum	1
54-241	Dramaturgy 3: Dramaturgy in Translation	9
54-219	Special Topics: Music Theater History and Repertoire	6
xx-xxx	Playwriting or approved sub	
82-xxx	Foreign Language, if needed *	9-12
54-245	Who Wore What: When, Where, and Why (or 54-246 in spring)	6
76-275	Introduction to Critical Writing (or in Jr fall)	9
xx-xxx	Non-Dramaturgy Elective	
xx-xxx	Approved Art/Arch History course (fall or spring)	6
		55-58

Spring		Units
xx-xxx	Playwriting or approved sub (if not in fall)	
54-xxx	Dramaturgy Production: Assistant (if not in fall)	3
54-200	Dramaturgy Forum	1
xx-xxx	Directed Elective	9
xx-xxx	Directed Elective	9
xx-xxx	Non-Dramaturgy Elective	6-9
82-xxx	Foreign Language, if needed *	9-12
54-256	Dramaturgy 4: New Play Dramaturgy	9
54-246	Who Wore What: When, Where, Why II (or 54-245 in fall)	6
xx-xxx	Approved Art/Arch History course (fall or spring)	6
		58-64

Junior Year

Fall		Units
54-200	Dramaturgy Forum	1
54-381	Special Topics: Feminist Theatre ***	6
54-xxx	Dramaturgy: Production (or in spring)	9/12
xx-xxx	Directed Elective	9
54-241	Dramaturgy 5:Dramaturgy in Translation	9
xx-xxx	Directed Elective	9
xx-xxx	Non-Dramaturgy Elective	6-9
54-245	Who Wore What: When, Where, and Why (or 54-246 in spring)	6
xx-xxx	Approved Art/Arch history course (fall or spring)	6
		52-64

Spring		Units
54-200	Dramaturgy Forum	1
xx-xxx	Directed Elective	9
xx-xxx	Directed Elective	9
54-381	Special Topics: Feminist Theatre ***	6
xx-xxx	Non-Dramaturgy Elective	6-9
54-254	Dramaturgy 7: New Play Development	6
54-xxx	Dramaturgy: Production (if not in fall)	9/12
54-246	Who Wore What: When, Where, Why II (or 54-245 in fall)	6
xx-xxx	Approved Art/Arch history course (fall or spring)	6
		49-61

Senior Year

Fall		Units
54-200	Dramaturgy Forum	1
54-381	Special Topics: Feminist Theatre ***	6
xx-xxx	Directed Elective	9
xx-xxx	Non-Dramaturgy Elective	6-9
54-247	Dramaturgy 6: In Company	9
54-xxx	Dramaturgy Research Hours	3
54-xxx	Dramaturgy: Production (or Capstone Project, if approved)	9/12
		34-46

Spring		Units
54-254	Dramaturgy 7: New Play Development (if needed)	9
54-200	Dramaturgy Forum	1
54-381	Special Topics: Feminist Theatre (if needed) ***	6
xx-xxx	Directed Elective	9
54-587	Dramaturgy Production (if not in fall)	12
xx-xxx	Non-Dramaturgy Elective	6-9
		43-46

All Students must complete a minor in Literature and Cultural Studies in the English Department.

DIRECTED ELECTIVES: EUROPEAN STUDIES & HISTORY	Units
Dramaturgy students take one European Studies course (cannot be an English course, but can be a History course)	9
Dramaturgy students take at least 3 History courses (two 200-level and one 300-level). One course must focus on history pre-1900, and one must focus on African, Asian, Latin American, or Caribbean studies.	27

DIRECTED ELECTIVES: FOREIGN LANGUAGE	Units
Dramaturgy students take at least one Foreign Language course at the 200-level or above.	12

NON-DRAMATURGY ELECTIVES:
Dramaturgy students take a minimum of seven Non-Dramaturgy Electives, 6-9 units each.

Notes:

* Dramaturgy students starting a modern language at the 100-level should begin in the fall of freshman year.

*** Dramaturgy students are required to take a total of 12 units of Special Topics in Drama: History, Literature and Criticism during their junior and senior year.

Faculty

WENDY ARONS, Professor, Dramatic Literature – Ph.D., University of California, San Diego; Carnegie Mellon, 2007–

NATALIE BAKER-SHIRER, Associate Professor Emerita, Voice & Speech – M.F.A., University of Pittsburgh; Carnegie Mellon, 1992–

CLAUDIA BENACK, Associate Teaching Professor, Music Theatre – M.F.A., Carnegie Mellon; Carnegie Mellon, 1993–

STEWART BLACKWOOD, Assistant Professor, Composition and Sound Design – M.F.A. , UC San Diego; Carnegie Mellon, 2023–

DICK BLOCK, Teaching Professor, Design – M.F.A., Northwestern University; Carnegie Mellon, 1988–

DAVID BOEVERS, Associate Professor, Production Technology and Management – M.F.A., Yale University; Carnegie Mellon, 2000–

C. TODD BROWN, Associate Teaching Professor, Lighting – B.A., Ohio State University; Carnegie Mellon, 2001–

JAMES CATON, Associate Teaching Professor, Dance New York School of Ballet; Carnegie Mellon, 1988–

JUDITH CONTE, Teaching Professor, Dance – B.F.A., University of Wisconsin/ Milwaukee; Carnegie Mellon, 1978–

TOME COUSIN, Professor, Dance – M.F.A., Long Island University ; Carnegie Mellon, 2011–

KAJA DUNN, Associate Professor, Anti-Racist and Culturally Competent Practice – M.F.A., Regent University ; Carnegie Mellon, 2022–

RICK EDINGER, Associate Professor, Music Theater – M.A., City University of New York: Hunter College; Carnegie Mellon, 2018–

MELINDA ESHELMAN, Associate Professor, Costume Design – M.F.A., Carnegie Mellon University; Carnegie Mellon, 2017–

JANET MADELLE FEINDEL, Professor Emerita, Voice/Alexander – M.F.A., Carnegie Mellon; Carnegie Mellon, 1996–

KRISTI GOOD, Assistant Professor, Dramaturgy – Ph.D., University of Pittsburgh; Carnegie Mellon, 2021-–

KYLE HADEN, Associate Professor, Acting – M.F.A., Columbia University; Carnegie Mellon, 2016–

ROB HANDEL, Professor, Dramatic Writing – M.F.A., Brown University; Carnegie Mellon, 2009–

HUGH HANSON, Associate Teaching Professor, Costume Production – M.F.A., University of Hawaii at Manoa; Carnegie Mellon, 2015–

JED ALLEN HARRIS, Associate Teaching Professor Emeritus, Directing – M.F.A., Carnegie Mellon; Carnegie Mellon, 1991–

KEVIN HINES, Associate Teaching Professor, Production Technology & Management – M.F.A., Yale University; Carnegie Mellon, 1998–

GARY KLINE, Teaching Professor, Voice – B.F.A., Carnegie Mellon; Carnegie Mellon, 1990–

GREGORY LEHANE, Professor Emeritus, Directing – M.F.A., Carnegie Mellon; Carnegie Mellon, 1991–

CINDY LIMAURO, Professor, Lighting Design – M.F.A., Florida State; Carnegie Mellon, 1987–

GARY LOGAN, Professor, Voice & Dialects – M.F.A., American Conservatory Theater; Carnegie Mellon, 2016–

BARBARA MACKENZIE-WOOD, Raymond W. Smith Professor Emerita, Acting – M.F.A., Carnegie Mellon; Carnegie Mellon, 1986–

ANTHONY MCKAY, Associate Professor, Acting – B.F.A., Carnegie Mellon; Carnegie Mellon, 1985–

MICHAEL MCKELVEY, Assistant Professor, Musical Theater – D.M.S, University of Texas-Austin; Carnegie Mellon, 2024–

CATHERINE MOORE, Teaching Professor, Movement – M.F.A., University of Cincinnati, College-Conservatory of Music; Carnegie Mellon, 2000–

ANNE MUNDELL, Professor Emeritus, Design – M.F.A., Brandeis University; Carnegie Mellon, 1989–

JOE PINO, Associate Professor, Sound Design – M.F.A., University of Virginia; Carnegie Mellon, 1999–

NICA ROSS, Associate Teaching Professor, Video and Media Design – M.F.A., NY Bard-International Center of Photography; Carnegie Mellon, 2016–

BRIAN RUSSMAN, Associate Teaching Professor, Costume Production – M.F.A., Ohio State University; Carnegie Mellon, 2009–

TINA SHACKLEFORD, Teaching Professor – M.F.A., University of California, San Diego; Carnegie Mellon, 2004–

LAWRENCE SHEA, Professor, Video and Media Design – M.F.A., Massachusetts College of Art; Carnegie Mellon, 2010–

ANDREW SMITH, Associate Professor, Acting – M.F.A., University of California, San Diego; Carnegie Mellon, 2014–

LISA VELTEN SMITH, Assistant Professor, Voice – M.F.A. , University of California San Diego; Carnegie Mellon, 2019–

MARY ELLEN STEBBINS, Assistant Professor, Lighitng – M.F.A., Boston University; Carnegie Mellon, 2024–

AUSAR STEWART, Assistant Professor, Voice – MFA , York University; Carnegie Mellon, 2019–

ROBERT THOMSON, Associate Professor, Lighting; Carnegie Mellon, 2014–

SUSAN TSU, Bessie F. Anathan Professor, Costume Design – M.F.A.,Carnegie Mellon, 2003–

DON WADSWORTH, Professor Emeritus, Voice & Speech – M.F.A., University of Pittsburgh; Carnegie Mellon, 1989–

BRIA WALKER-RHOZE, Assistant Professor, Acting – M.F.A., Acting, National Theater Conservatory; Carnegie Mellon, 2023–

KAF WARMAN, Teaching Professor, Movement – M.F.A., Goddard College, Ecole; Carnegie Mellon, 1996–

CHELSEA WARREN, Associate Professor, Scenic Design – M.F.A., Northwestern University ; Carnegie Mellon, 2023–

KIM WEILD, Associate Professor, Directing – M.F.A., Columbia; Carnegie Mellon, 2017–

MISO WEI, Assistant Teaching Professor, Stage and Production Management – M.F.A. , University of California, San Diego; Carnegie Mellon, 2020–

YONG SUK YOO, Associate Professor, Directing – M.F.A, California Institute of the Arts; Carnegie Mellon, 2024–

TJ YOUNG, Associate Professor, Dramaturgy – M.F.A., Texas State University; Carnegie Mellon, 2022-–

BETH ZAMBORSKY, Associate Teaching Professor, Scenic Art & Drawing – B.S., La Roche University; Carnegie Mellon, 2003–

School of Drama Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

54-011 Introduction to Alexander Technique

Fall: 1 unit
TBD

54-012 Warmup

Spring: 1 unit
Drama majors only. Freshman Acting Warm Up is a three-day-a-week course which is designed to help the actor prepare mentally and physically for daily training and/or rehearsal. The preparations are based in yoga exercises and are meant to help the actor gain a greater self-awareness, fuller breathing, a greater degree of being centered, and focused on the immediate moment.
Prerequisite: 54-011

54-101 Acting I

Fall: 10 units
A knowledge and beginning understanding of the components of acting. Basic exercises, improvisations and prepared work in relaxation, concentration, imagination, communication. The ability to create the reality of a given situation in theatrical terms. Craft fundamentals in preparation for scene study. The beginning development of the students creative resources. This course is open to Drama majors only.

54-102 Acting I

Spring: 10 units
A knowledge and beginning understanding of the components of acting. Basic exercises, improvisations and prepared work in relaxation, concentration, imagination, communication. The ability to create the reality of a given situation in theatrical terms. Craft fundamentals in preparation for scene study. The beginning development of the students creative resources. This course is for Drama majors only.
Prerequisite: 54-101

54-103 Speech I

Fall: 4 units
(Speech I) The course introduces students to the pronunciation of the sounds of Standard American English pronunciation as presented by Edith Skinner in her textbook SPEAK WITH DISTINCTION. The International Phonetic Alphabet is used to introduce the students to a distinct symbol for each vowel, diphthong and consonant sound. This process will strengthen the student's placement of sounds and will help to illustrate and control regional characteristics. The work is applied to regular individual presentations of various texts. Phonetic transcription is required of class participants throughout the course. Written accuracy of the sounds are required and assigned regularly. This course is open to first year Acting majors who have been accepted to the School of Drama only.

54-104 Speech I

Spring: 6 units
The Spring course continues to develop the foundational work from the pervious term. This includes the identification and pronunciation of the sounds of Standard American English. Students will study the physical placement and pronunciation of each sound in isolated applications. The International Phonetic Alphabet (IPA) has been introduced and will continue with further diphthong and triphthong sounds and symbols. Further study will involve strong and weak forms of words, linking 'r' sounds and syllabic consonants; students will apply the advanced speech work to challenging extravagant material as well as exercises with commonly mispronounced words.
Prerequisite: 54-103

54-105 Voice for the Stage I

Fall: 5 units
An Introduction to the fundamental foundation of speaking voice training for the actor; physical awareness, breath, and the free release of sound. Resonance, range, articulation, vocal clarity and expressiveness are also emphasized. The work is based upon the classic progression of voice exercises of Kristin Linklater. The exercises are designed to liberate the voice from habitual psychophysical tensions as well as developing sensitivity to impulse. This approach offers the possibility of liberating your natural speaking voice rather than adopting a vocal technique in order to truthfully embrace the performer's instincts. The natural voice is transparent, revealing, connected to thought, emotion, sound, and the spoken word; elements that are essential to an authentic embodiment of a character.

54-106 Voice for the Stage I

Spring: 5 units
Introduction to basic speaking voice and Alexander Technique work. Actors explore building a vocal preparation employing the principles of the Alexander for actor?s speaking voice through explorations that help develop awareness of the head, neck torso relationship and the movement of the spine; vocal release, breath support, stamina. range, use of resonators and the application to text. Actors learn to identify components of healthy and unhealthy voice usage, basics of vocal anatomy and strategies for maintaining vocal health. Writing exercises are employed to help actors connect the voice to creativity and imaginative, essential for the actor?s development.
Prerequisite: 54-105

54-107 Movement I

Fall: 4 units
This course serves as a foundation for all future movement studies. Kinesthetic awareness and responsiveness is developed through the introduction of the Viewpoints method of physical training. The importance of physical expressivity and specificity in storytelling is achieved by the creation of physical movement based compositions. This is a required course for all first year undergraduate Acting and Musical Theatre and Directing students.

54-108 Movement I

Spring: 4 units
This course is designed to continue the physical actor training sequence begun in the previous semester by introducing new methodologies and working vocabularies. This course examines and explores the use of the human body as an expressive artistic instrument of communication. Concepts of the body in relation to Time, Space, Weight, and Energy will be explored. This is a studio course in which learning is experiential. In addition to daily class activities and exercises, assignments will include a written test and solo presentations/performances. Admission to this course fulfills a requirement for first year undergraduate acting and music theatre majors
Prerequisite: 54-107

54-109 Dramaturgy 1: Approaches to Text

Intermittent: 9 units
This course is an introduction to dramaturgical analysis of a play; the goal of this course is to provide students with a number of text analysis "tools" to use in understanding plays for production.

54-110 Text for Actors

Fall: 2 units
This class is in conjunction with Acting I in the School of Drama. The actor/director learns how to investigate the written text and translates it actively for performance.

54-111 Theatre Process for Non-Majors

Fall and Spring: 6 units
This course is designed to increase students' appreciation and awareness of theatrical art through lectures, discussion, projects, and live performance.

54-115 Rhythmic Exploration

Spring: 1.5 units
Optional course.

54-117 Design Collaboration Project

Spring: 3 units
This course is intended to provide students with hands-on experience in the process of collaboration on a design for a production. Students in the course will work in teams to design a hypothetical production of a given play.

54-119 Vocal Technique

Fall: 1 unit
Singing technique for first-year Music Theatre students.

54-121 Directing I: A Director's Mindset

Fall: 9 units
A discovery of the director's mindset. Through discussions, readings, exercises, projects and explorations, this course is intended to give the aspiring director a foundation for the continual investigation into multiple forms of expression that might feed the director's imagination and toolbox.

54-122 Directing I: A Director's Preparation

Spring: 9 units
A continuation of the previous semester focusing on a director's preparation.
Prerequisite: 54-121

54-123 Dance Technique I: Physical Mechanics and Anatomy

Fall: 5 units
This course uses Classical technique (Ballet) to build body placement, alignment and muscular strength and flexibility. Designed to help the student develop a way of learning how to work and train for any dance form. This technique is the basis of the choreography in American musical theater. This course is for Music Theatre majors only. Permission of instructor.

54-124 Dance I: Applying Dance Technique

Spring: 5 units
This course continues Classical technique (Ballet) to build body placement, alignment and muscular strength and flexibility. Designed to help the student develop a way of learning how to work and train for any dance form. This technique is the basis of the choreography in American musical theater. This course is for Music Theatre majors only. Prerequisite: 54-123 and permission of instructor.
Prerequisite: 54-123

54-125 Music Skills I

Fall: 4 units
The students explore the basics of music theory, which includes intervals, rhythm, notation and musical vocabulary. Emphasis is on acquiring these basic skills through sight singing. For School of Drama MT students only.

54-126 Music Skills II

Spring: 4 units
The students explore the basics of music theory, which includes intervals, rhythm, notation and musical vocabulary. Emphasis is on acquiring these basic skills through sight singing.
Prerequisite: 54-125

54-134 Writing for Television

Spring: 9 units
Students will write an original pilot, focusing on structure, character, and an analysis of what makes great TV.

54-135 The Basics of Self-Producing: How to Put Up Your Show in NYC and Get It Reviewed

Fall and Spring: 6 units
For any actor/writer/director/theatre artist in New York City, the time between jobs can feel stressful and frustrating. Self-producing is the quickest way to get your work on stage without permission from anyone else or having to adhere to anyone else's restrictions. From blurbs to budgets to rehearsal space to press releases to equity paperwork, this course covers everything you need to know in order to get your work produced and noticed in New York City without breaking the bank. This course will draw from readings on independent theatre, interviews with working independent producers in New York, and the working experience of Anderson Cook, author/producer of The Disembodied Hand That Fisted Everyone to Death - the Musical!, Blatantly Blaine, Pop Punk High, Donny and Kelly Save the Slumber Valley ASPCA, and more - all produced and reviewed in NYC.

54-151 Stagecraft

Fall and Spring
The stagecraft class is designed to provide an introductory level of technical training in all the theatrical technical disciplines over the course of two semesters. The intent is to produce people who can capably fill roles on production crews and perhaps serve as an assistant to the head of the crew. Course content will cover materials, tools and amp; equipment, procedures, safety and operations for Carpentry, Props, Paints, Media, Costumes, Lights, Sound, Rigging, and Run Crew. As well as providing opportunity and experience to grow as technicians, this content will also help establish a foundation to begin the process of becoming managers and designers. As craft skills are often best communicated in a master/apprentice environment this course is set up as a mentored practical experience. This course requires significant additional scheduled time on evenings and weekends for crew calls, which are an important element of the course.

54-152 Stagecraft

Spring
The stagecraft class is designed to provide an introductory level of technical training in all the theatrical technical disciplines over the course of two semesters. The intent is to produce people who can capably fill roles on production crews and perhaps serve as an assistant to the head of the crew. Course content will cover materials, tools equipment, procedures, safety and operations for Carpentry, Props, Paints, Media, Costumes, Lights, Sound, Rigging, and Run Crew. As well as providing opportunity and experience to grow as technicians, this content will also help establish a foundation to begin the process of becoming managers and designers. As craft skills are often best communicated in a master/apprentice environment this course is set up as a mentored practical experience. This course requires significant additional scheduled time on evenings and weekends for crew calls, which are an important element of the course.

54-157 Production Science

Fall: 6 units
Students in the Production Science course are exposed to the very fundamentals, the primitives, of entertainment technology. The intent is to provide the absolutely strongest beginning for all the work to come, to provide a solid foundation for students and instructors to build upon. Production professionals routinely perform organizational tasks. In order to be able to meet that challenge, students will need to build a toolkit of information and procedures. That toolkit will be comprised of knowledge of the kinds of parameters and techniques that are normally selected, the indices that parameters and techniques are evaluated against, and many of the wide range of issues that might point a manager toward one decision or another. There also exists an entire pantheon of information that people typically learn "on the job." Activities and information presented in this course are designed to try to expose students to as much of this on the job type development as possible with the goal of leapfrogging them past the bottom rung of the workplace ladder. Drama Design/Production majors only, or with instructor permission.

54-158 Production Planning

Spring: 6 units
Students in the Basic PTM course are exposed to the very fundamentals, the primitives, of entertainment technology. The intent is to provide the absolutely strongest beginning for all the work to come, to provide a solid foundation for students and instructors to build upon. Production professionals routinely perform organizational tasks. In order to be able to meet that challenge, students will need to build a toolkit of information and procedures. That toolkit will be comprised of knowledge of the kinds of parameters and techniques that are normally selected, the indices that parameters and techniques are evaluated against, and many of the wide range of issues that might point a manager toward one decision or another. There also exists an entire pantheon of information that people typically learn "on the job." Activities and information presented in this course are designed to try to expose students to as much of this on the job type development as possible with the goal of leapfrogging them past the bottom rung of the workplace ladder. PREREQUISITES: Declared Design/PTM focus in the School of Drama FOR: First Year Undergraduate Students

54-159 Production Practicum

Fall: 6 units
Hands on experience in most aspects of installing and running a production.

54-162 Introduction to Costume Design

Spring: 6 units
A rigorous introductory studio course for newly declared School of Drama Costume Design Sophomores in their fourth semester of matriculation. Basics of the design process are covered as well as drawing, sculpture, semiotics, play and character analysis, research and character building are explored. An intensive collaboration project with students of other design disciplines comprises the second half of the course. All others: interview/portfolio review and instructor permission. FOR: 3rd semester Sophomore Costume Designers and students outside of School of Drama.
Prerequisites: 54-172 and 54-171 and 54-231 and 54-232

54-163 Production for Non Majors

Fall: 6 units
Non-major involvement in a Schools of Drama production or classroom project.

54-166 Introduction to Sound Design for Theatre

Spring: 6 units
Students explore the basic principles and theories of sound design from technical, psychological and aesthetic standpoints. Course work includes instruction in the controllable properties of sound, practical planning of sound plots, cue creation, and the design process. Prerequisites: Basic Design and Design For The Stage. Drama majors have priority, however this course is also open to Music Technology majors and minors, or with permission of instructor.
Prerequisites: 54-172 and 54-171 and 54-231 and 54-232

54-167 Acting for Directors I

Fall: 10 units
Acting I for Director BFA students.

54-168 Acting for Directors I

Spring: 10 units
A knowledge and beginning understanding of the components of acting. Basic exercises, improvisations and prepared work in relaxation, concentration, imagination, communication. The ability to create the reality of a given situation in theatrical terms. Craft fundamentals in preparation for scene study. The beginning development of the students creative resources. This course is for Directing students only.

54-169 Studiocraft 1

Fall: 13 units
The studiocraft course provides beginning level instruction in Drawing, Hand Drafting, and CAD Drafting.

54-170 Studiocraft 2

Spring: 8 units
Using the basic skills learned in the first semester, we will develop better and explore the use of basic drafting processes to solve more complex problems. The conventions of drafting do not change with the different types of drawings so line weight, clarity, neatness and organization will continue to be emphasized. We will also begin to discuss ways to improve the cosmetics of draftings. As before, classes will consist mostly of lecture and demonstration. Some class sessions will be dedicated to working on assigned projects, generally one class meeting per project.
Prerequisite: 54-169

54-171 Basic Design 1

Fall: 6 units
A year-long studio course that explores the principles and elements of design utilizing discreet exercises and projects first semester. Research and reports expose the students to designers, theatres and artists of note in the world. Second semester focuses on the semiotics of the visual and aural aspects of theatrical design. Projects fold in each of the disciplines of scene, costume, lighting, sound and media design. PRE-REQUISITE: Declared Design/PTM focus in the School of Drama. FOR: First Semester Design/PTM Undergraduate Students only.

54-172 Basic Design 2

Spring: 6 units
A year-long studio course that explores the principles and elements of design utilizing discreet exercises and projects first semester. Research and reports expose the students to designers, theatres and artists of note in the world. Second semester focuses on the semiotics of the visual and aural aspects of theatrical design. Projects fold in each of the disciplines of scene, costume, lighting, sound and media design. PRE-REQUISITE: Declared Design/PTM focus in the School of Drama. FOR: Second Semester Design/PTM Undergraduate Students only
Prerequisite: 54-171

54-175 Conservatory Hour

Fall: 1 unit
A discussion class for first-year Drama students. Open to non-majors interested in declaring a Drama minor.

54-176 Conservatory Hour

Spring: 1 unit
A year-long discussion class for first-year Drama majors. Open to non-majors interested in declaring a Drama minor.

54-177 Foundations of Drama I

Fall and Summer: 6 units
In this course, students receive training in the basic analysis of scripts to determine key elements of structure, plot, characterization, thematic content, theatricality, and aesthetics. In addition, the course provides training in dramaturgical research and writing.

54-179 Making Room: Study of Black American Playwrights

All Semesters: 6 units
This course, a research forum, is an opportunity to investigate, share and analyze the work of Black American Playwrights. Classics from artists like Marita Bonner, Georgia Douglas Johnson and Pearl Cleage are entryways to the dynamic expressions of Black authorship. This course will add to the analysis pool of both classic and contemporary text. Expanding the assembly's general knowledge, students will be invited to share work that sparks their interest as well.

54-180 Introduction to Playwriting

Fall and Spring: 9 units
This course provides a basis and the building blocks for beginning playwrights. This course will serve as an introduction to character development, monologues, subtext, action, style, and pacing in theatrical writing. Students will write short theatrical pieces in a workshop setting, where feedback will be given by the instructor and other students.

54-183 Introduction to Playwriting

All Semesters: 9 units
What is a play? And why bother writing one? There is no correct way to write a play, but there are distinctive elements to stories written for the stage. Students in this course will define what these elements are and practice using them to write plays of their own. Aristotle's Poetics will provide a framework and a common vocabulary as students explore plays by Lynn Nottage, Clare Barron, and other contemporary playwrights. The first half of the course will be reading-intensive and discussion-based with some short writing exercises. In the latter half of the semester, students will write and revise original short plays. No prior theatrical or creative writing experience required.

54-184 Dramaturgy 2: Introduction to Production Dramaturgy

Intermittent: 9 units
Dramaturgy 2 introduces students to the essential tasks and processes that dramaturgs perform on productions of established plays (i.e., plays whose texts are not changing). Students perform text analysis, conduct research, curate and present information, develop and provide critical feedback on production work in progress, and design pre- and post-performance experiences for an audience. This is a writing-intensive course with a high reading load. Dramaturgy 2 is a prerequisite for higher-level courses in the Dramaturgy curriculum.

54-187 Writing for an Inspired Life

Fall: 9 units
Each of us has a deep pool of creative life within us, but often as we grow older we lose touch with that life source that guided us as children to explore, dream, and create. What seeds exist within you that have yet to grow? Are there loose pages to a film script, a poetry collection, or illustrations for a comic that you haven't had the space to explore and cultivate? This class will provide a safe weekly space to develop, explore, and reignite your creative passion project. We will give ourselves the gift of time. In this class, we will develop our artist self through small daily intentional exercises, workshop our pieces in a space without judgment of it being "good" (to me as long as you try that is what matters), and learn from inspiring media and great guest teachers who will visit our class and lead workshops on cultivating an inspired life. This class is open to all CMU students who are curious about how to use art as fuel for their personal, creative, and professional lives: playwrights and engineers alike.

54-189 Advanced Writing for Television

Intermittent: 9 units
In this course students will be introduced to the major components of writing for TV, including character and structure, while analyzing genre television and pilot writing. Exercises designed to familiarize students with the tools available to TV writers will be assigned, and over the course of the semester, students will develop an original TV pilot. (Students who have not taken "Intro to TV Writing" need to seek permission from the instructor, but don't let that deter you!)
Prerequisite: 54-134

54-190 Intro to Writing the Television Pilot

Spring: 9 units
When you write your television pilot, you are crafting the engine that will generate year after year of stories. The opening image makes clear that this is a show like no other, the show only you could create. The first ten minutes set the bomb that's going to blow up your hero's world. Your pilot as a whole lets us know what we can expect here every week, with our new family, as they look for a way to get through this thing. In this class, we will meet and master the elements of the television pilot, then use them to build a marketable script. We will devote ourselves extensively to practicing the habit of revision.

54-191 Acting for Non-Majors

Fall and Spring: 9 units
This course is designed to develop the students' awareness of the actor's process and to foster a general sense of theatre as an area of human endeavor. Students will be introduced to basic communication skills, including physical and vocal presence in front of an audience. The course will also develop an introductory level of acting skill through the use of regular warm-ups, theater games, improvisation, and simple scene study. Scenes will be selected from a diverse range of playwrights and students will examine the political, cultural and social context of each play. The course will also provide an introduction to basic theater terminology and foster the ability to respond to and reflect on theatrical performances.

54-192 Acting Ensemble for Non-Majors

Fall and Spring
This course offers an opportunity to work with undergraduate student directors on their projects, which will widely range in material (e.g. adaptations of literature to television scripts to musical theatre). Directors will hold auditions in the first week of school for their projects, and the actors who are cast will then have the opportunity to enroll in this class. Depending on the project, actors may be cast for one mini or two, potentially working with more than one director. Actors will be required to attend rehearsals outside of class up to 5 hours a week, and to attend class when showings happen. Audition required at the beginning of the semester. Admittance to class by permission of professor. If you are interested, add yourself to the waitlist.*****

54-193 Acting for Non-Majors: Improv

Intermittent: 9 units
This course will introduce students to the history and components of improvisational performance. Students will explore short and long form improv styles and work in teams to create original, in-the-moment performances. We will also investigate real-world applications of improv techniques and imagine a future rooted in cooperation. A desire to work together is essential for this class.

54-195 Mystic and Supernatural Writing for the Screen and Stage

Fall: 9 units
Are you obsessed with all things supernatural, misunderstood, and/or mystical, ranging from bigfoot/sasquatch all the way to Gods and demons? This course aims to channel that interest into generated work, newly written screenplays as well as plays for the stage. I believe that these mediums are tailor made for supernatural elements because of the intimate nature of theatre and visual spectacle of the screen. For this course, we will use Noh theatre, African folklore, urban legends, and more to give shape to our individual fascinations. We will "give them shape" by reading plays such as The Piano Lesson by August Wilson and watching films such as Candyman (2021). The first mini will revolve around writing exercises and in-class discussion about what we are reading and watching. The second mini will revolve around the generation of pages depending on your goals. Pages can be ten-minute plays, short films, and more. There are NO WRONG ANSWERS and NO WRONG WAYS of going about this in the course other than not putting your best foot forward. I encourage students to explore their interests regardless of how developed they may be or how familiar with writing you may be as the course is open for all students both in the SOD and outside of it. Come with a positive outlook, various stages of ideas, and a willingness to grow with others!

54-196 Introduction to 10-Minute Plays

Spring: 9 units
Wanna write a play but think it's too hard? Maybe this is a way to start. This class focuses on 10-minute plays. It is designed to provide non-theater majors with an introduction to the writing and appreciation of short plays. In this class, we will have the opportunity to conduct stage reading of short plays of your interest, understand and analyze the structure of short plays, and practice your writing skills. This course will be writing-feedback based workshop, you'll get a chance to share your works with your peers and gain their feedbacks. Students are expected to complete four original 10-minute plays by the end of the semester.

54-198 Plays With Words: Exploring Language-Driven Theater

Fall and Spring: 9 units
This course will provide students with an understanding of the category of plays that use language as their main engine of storytelling. Students will learn to identify and analyze the conventions of language plays, as well as practicing techniques to write their own. Some of the elements of language plays discussed in this course include plays with non-naturalistic language, emotionally expressive language, and action-driven language. The course will culminate in a final project in the form of a completed, full-length language play.

54-200 Dramaturgy Forum

Fall and Spring: 1 unit
Programmed and taught by senior students in the Dramaturgy program, this course is required for all Dramaturgy majors and meets once per week to discuss issues and topics of significance to the dramaturgy community.

54-201 Acting II

Fall: 12 units
Scene study: the fundamental techniques needed to participate in the developing conflict within the imaginary world. Character building through unfamiliar behavior and beliefs; relationships; language. Spring semester: The use of classical texts and ensemble playing. The deepening of the actors inner resources to be supported by the craft techniques.
Prerequisites: 54-102 and 54-101

54-202 Acting II

Spring: 12 units
Scene study: the fundamental techniques needed to participate in the developing conflict within the imaginary world. Character building through unfamiliar behavior and beliefs; relationships; language. Spring semester: The use of classical texts and ensemble playing. The deepening of the actors inner resources to be supported by the craft techniques.
Prerequisite: 54-201

54-203 Voice and Speech II

Fall: 4 units
The actors take a more concentrated approach to elevated text. The course focuses on the effective production of classical text. The warm up sessions are geared towards preparing the student actors for the extravagant language from Shakespeare?s plays and sonnets. Meter, imagery and further specific text work is also employed to encourage each student to find clear shape in the work. A repertoire of at least five classical monologues will come from the course work.
Prerequisites: 54-103 and 54-104

54-204 Voice and Speech II

Spring: 4 units
The actors take a more concentrated approach to elevated text. The course focuses on the effective production of classical text. The warm up sessions are geared towards preparing the student actors for the extravagant language from Shakespeare?s plays and sonnets. Meter, imagery and further specific text work is also employed to encourage each student to find clear shape in the work. A repertoire of at least five classical monologues will come from the course work.
Prerequisites: 54-203 and 54-103 and 54-104

54-205 Dance II: Pillars to Build Dance Technique

Fall: 3 units
This course is designed to build on the technical foundation, work habits and professional behavior established in Ballet I. The material presented expands the classical dance vocabulary to the next level of difficulty. Course closed: Only for Music Theatre majors in Drama. Prerequisite: Permission of instructor
Prerequisites: 54-124 and 54-123

54-206 Dance II: Pillars to Build Dance Technique

Spring: 3 units
This course continues to build on the technical foundation, work habits and professional behavior established in Ballet I. The material presented expands the classical dance vocabulary to the next level of difficulty. Course closed: Only for Music Theatre majors in Drama.
Prerequisite: 54-205

54-207 Movement II

Fall: 4 units
Movement II is a Lecoq-based course that weaves together three approaches to physical development: movement foundations, mime, and mask. Foundational work covers the basic principles and practices required to gain a solid physical technique as an actor: grounding, centering, balance, tension/relaxation, tempo variance, listening, levels of play, physical imagination, etc. Mime studies of dramatic action sequences such as pulling, pushing, climbing, throwing and classical mime illusion encourages economy and precision. Mask work conceals the face and reveals the body, forcing the actor to rely less on facial expressions and focus more on the stories being projected by the body. The main objective of this course is to encourage a disciplined mastery over bodily control and physical expression that has a direct application to playing a variety of theatrical styles. Limited to Acting/MT majors only.
Prerequisites: 54-108 and 54-107

54-208 Movement II

Spring: 3 units
This term is divided between two classic physical forms: Commedia dell'Arte and Clowns. In the first half of the semester students wear the half-masks of the archetypal Commedia characters (Harlequin, Pantalone, et al), to learn their psychology and physicality, improvise on historical and contemporary scenarios, and apply Commedia technique to modern comedy. Commedia dell'Arte gives them the tools to tackle physical comedy from any era, past or present. In the second half of the term students discover their personal Clowns. This clown has nothing to do with the American Barnum and amp; Bailey Circus clown; this is not a character or caricature, but rather a revelation of the clown each student hides under the mask of adulthood. Discovering this clown gives them all a way to laugh at themselves, to uncover what makes each individual uniquely funny; it also lets them see how we only laugh at truth and in the personal material lies universal humor. Inside this freedom is the technique to know what's funny and why, and the ability to apply these rules in comedy."
Prerequisites: 54-107 and 54-207 and 54-108

54-209 Voice and Speech II: Practicums

Spring: 3 units
TBA

54-211 Actor Dance II

Fall: 3 units
This course introduces the basic, fundamental vocabulary of Classical technique (Ballet) to train the body in proper alignment, placement, and muscular strength. Course closed: Only for Acting majors in Drama. Prerequisite: Permission of instructor
Prerequisites: 54-101 and 54-102

54-212 Actor Dance II

Spring: 3 units
Beginning Ballet. A continuation of Classical technique (Ballet) and a unit of social dance styles, waltz, polka, foxtrot, tango, swing. Course closed: Only for Acting majors in Drama.
Prerequisites: 54-102 and 54-211 and 54-101

54-213 Singing for Actors II

Fall: 3 units
The students have a class voice experience which includes a physical and vocal warm-up and discussion and practice of healthy singing technique. There is group and individual rehearsal of potential audition and performance material. Toward the end of the term, there are weekly opportunities to perform in public, thus preparing for auditions.
Prerequisites: 54-102 and 54-101

54-214 Singing for Actors II

Spring: 3 units
The students have a class voice experience which includes a physical and vocal warm-up and discussion and practice of healthy singing technique. There is group and individual rehearsal of potential audition and performance material. Toward the end of the term, there are weekly opportunities to perform in public, thus preparing for auditions.
Prerequisites: 54-102 and 54-101

54-216 Technical Solutions from the OSF

Spring: 3 units
This course is an introduction to planning for repertory theater using the Oregon Shakespeare Festival as a model. Students will explore topics including the inherent tensions between time and space created by a rep, interdisciplinary technical design, automation, collaborating with designers, and common rep pitfalls. By course end, students will not only have a working analysis of the inner machinations of a repertory model, but also a deeper understanding of regional theater art making overall.

54-217 Jazz II

Fall: 2 units
This course is designed to incorporate the strength of classical dance technique to a jazz dance style. Training the body in a variety of contemporary Jazz styles, i.e. Latin, Blues, Lyric, African, using body isolations and rhythmic patterns. Course closed: Only for Music Theatre majors in Drama. Prerequisite: Permission of instructor
Prerequisites: 54-123 and 54-124

54-218 Jazz II

Spring: 2 units
This course continues to incorporate the strength of classical dance technique to a jazz dance Training the body in a variety of contemporary Jazz styles, i.e. Latin, Blues, Lyric, African, using body isolations and rhythmic patterns. Course closed: Only for Music Theatre majors in Drama.
Prerequisite: 54-217 and Permission of instructor
Prerequisite: 54-217

54-219 Special Topics: Music Theater History and Repertoire

Fall: 6 units
This course is a survey of musical comedy and musical theatre performances throughout history. Often considered a quintessential American theatrical form, we will also consider what "musical theatre" or "musical drama" means beyond the borders of the United States. The course will primarily focus in the time frame of 1860-present. We will examine the historical background, development and evolution of form, as well as impact and proliferation of this performance style. The class will look at all levels of musical theatre: music/lyrics, book, production, direction, choreography, marketing, popularity, cultural impact, globalization, etc. The course will involve lecture-based, discussion-based, and project-based styles of engagement. For this section of the course, students will engage in practice-based learning to build a diverse repertoire of songs. They will also continue to reinforce the principals of music theory learned in the first year by learning a new piece of repertoire every week that coincides with said week's topic.
Prerequisites: 54-281 or 54-500

54-220 Acting A Song

Spring: 4 units
This class is for Music Theatre majors only. This class explores the personal relationships between performer and song. Exercises include Class Interrogation, Story Telling, and Text Analysis. Based primarily on the personal experience the actor brings to the text, rather than technical aspects. Acting a Song is the prerequisite for Cabaret class.
Prerequisite: 54-500

54-221 Directing II: In the Studio

Fall: 9 units
Directing II This is a fall-semester course for 2nd-year Directing students and others with special permission introducing the fundamentals of the director's craft: text analysis; the concept of Action and amp; Change, directors units and amp; transitions) Visual Vocabulary and amp; Staging. Tools including planes, levels, body positions, composition, picturization, emphasis and amp;movement, and the ground plan. Work includes unscripted exercises, scene breakdowns, detailed character analysis, and a final 7 to 10 minute devised performance

54-222 Directing II: In The Room

Spring: 9 units
A continuation of the work done in the first semester of Directing II. This course is for Directing sophomores and BXA Directing students only.
Prerequisite: 54-221

54-223 Tap II - Rhythmic Technique/Foundational to Complex

Fall: 2 units
This course trains the student to develop a comfort level to execute percussive sounds, in a variety of percussive rhythmic patterns while applying the technical foundation of alignment and placement from classical technique. Course closed: Only for Music Theatre majors in Drama.
Prerequisite: Permission of instructor
Prerequisites: 54-123 and 54-124

54-224 Tap II: Rhythmic Technique/Foundational to Complex

Spring: 2 units
This course continues to technically train the student in a variety of percussive rhythmic patterns. Course closed: Only for Music Theatre majors in Drama.
Prerequisite: 54-223

54-225 TD Case Studies

Fall: 3 units
This course will through a weekly round table discussion look at examples of real-world experiences involving technical direction concerns, obstacles, and dilemmas. Each week the class will be given a situation or example that occurred in the past during production of a Pittsburgh Civic Light Opera summer season. The students mediated by the instructor will brainstorm and discuss reactions and solutions to these problems. Realizing that often there are many solutions to the same TD problems depending on any given situation, not only will the discussion look at what was done at the time of the example but how other methods might be weighed against those used. Once the group comes to a consensus on the week's issue the students will be responsible for outlining the process to correct the problem, avoid future similar concerns, or alter the contributing situations. This outline might be in the form of mechanical drawings, excel files, word docs, or actual outlines.

54-227 How to Write a Shakespeare Play

Fall and Spring: 9 units
There are dozens of books that present a set of rules for writing a play, but not one of them will result in a play like those written by the world's most beloved playwright. This is madness. Whom should we take as a model if not Shakespeare? Can we invent an alternative set of rules that will permit mad shifts of tone, disregard for unities of time and place, stages shared by people from different social classes, inside-out characters (driven by individual psychology) alongside outside-in characters (driven by archetypal imperative), bad puns, dirty jokes, storms, slapstick, and the raising of unanswered (and unanswerable) questions? In this course, we will ransack our colleague Shakespeare's work to find strategies we can steal and reshape for our own purposes, through a series of writing projects on the level of the line, the speech, the scene, the act, and the play.

54-229 The Biz - In Practice

Fall: 4 units
Students will assess and investigate their personal professional path using the information and experiences from The Business of Acting course.

54-230 Make-Up for Designers

Spring: 6 units
This course is structured as a lecture/demonstration and lab employing and exploring the principles of stage makeup, the variety of materials available and the practical application of these materials. The course is designed to provide the student with a working knowledge of broad-based application procedures, materials and techniques. We will also explore the principles of characterization allowing for the development, planning, and execution of effectual character makeup designs. The student should also be able to determine the stage-worthiness of a makeup application and how light will influence its appearance.

54-231 Design for the Stage

Fall: 6 units
This course is divided into four minis to introduce the student to the design process for costumes, lighting, scenery and sound. For Drama majors only, or instructor permission
Prerequisites: 54-170 and 54-171 and 54-172 and 54-169

54-232 Design for the Stage: Lighting

Spring: 4 units
This course is an introduction to the process of lighting design. Students will engage in various hands-on light lab exercises and group projects to explore the physical properties of light in storytelling. Discovery and experimentation are encouraged. Students will begin to build a process for visualizing a play though the principles of design, interpreting a text, and communicating ideas.
Prerequisites: 54-170 and 54-172 and 54-171

54-233 Acting For Directors II

Fall: 12 units
Acting II for Directors

54-234 Acting For Directors II

Spring: 12 units
Acting II for Directors

54-237 Scenic Painting I

Fall: 6 units
This is a one semester studio course in the foundations of scenic painting for theater and related fields. Students will complete projects that address the following topics: preparation of and paint techniques for both soft goods and hard covered surfaces, drawing and painting to scale, representing textures in both 2 and 3 dimensions, and color mixing. Subject matter changes often and may include: architecture, natural and man-made textures, drapery, interior/exterior scenes, the human figure, still life objects.

54-238 Scenic Painting II

Spring: 6 units
This is a studio course in the foundations of scenic painting for theater and related fields. Students will complete projects that address the following topics: preparation of and paint techniques for both soft goods and hard covered surfaces, drawing and painting to scale, representing textures in both 2 and 3 dimensions, and color mixing. Subject matter changes often and may include: architecture, natural and man-made textures, drapery, interior/ exterior scenes, human figure, still life objects.

54-239 History of Architecture and Decor 1: Ancients to Gothic

Fall: 6 units
This course is a survey of architecture, furniture and interiors from ancient times to the Gothic period. A lecture/slide course, the discussion of architecture is done with reference to social, political and economic history.

54-240 History of Architecture and Decor 2: Renaissance to the 21st Century

Spring: 6 units
This course will cover the styles and movements of architecture, furniture and to a lesser degree, the decorative arts, from the Italian Renaissance to modern day architecture in the West as well as the major Chinese, Indian and Islamic periods in the East. Discussions will include the social, economic, religious and political history of each period in as much as it helps illuminate the reasoning behind the visual nature of its architecture.

54-241 Dramaturgy 3: Dramaturgy in Translation

Fall: 9 units
Theatre is a global art form, and the average student's knowledge of world drama is made possible by the practice of translating seminal works into the English language. But what if a play has more than one translation? How does a theatre artist/scholar choose which text is right for their project? And what do you do when you don't speak the other language in question? Dramaturgy 5: Dramaturgy in Translation will introduce students to contemporary theories and questions of translation studies and equip them with a set of best practices for selecting the most appropriate text for their needs. Speaking a language in addition to English is not required for this course.
Prerequisites: 54-109 and 54-184

54-242 Improvisation

Spring: 2 units
This course is for Sophomore Actors only. This course not only sharpens their skills as ensemble performers, but also allows for more playfulness, creativity and exploration, cultivating risk-taking and a certain abandon. The course concentrates on non-verbal psychological improv, helping actors achieve a kind of physical truth and spontaneity, while becoming aware of the importance of the body in conveying information.
Prerequisites: 54-102 and 54-101

54-245 Who Wore What: When, Where, and Why

Fall: 6 units
This year-long course surveys the development of garments in the Western World from ancient civilizations to the first half of the 20th century. We will look at the progression of the shapes and forms that aesthetically define the clothing of each period, while also exploring the broader relationship of costume to culture and society through history. The course will comprise visual presentations of the art of each period, especially pertaining to representations of clothing, along with research projects, quizzes and exams.

54-246 Who Wore What: When, Where, Why II

Spring: 6 units
The 2nd part of this year-long course surveys the development of garments in the Western World from ancient civilizations to the first half of the 20th century. We will look at the progression of the shapes and forms that aesthetically define the clothing of each period, while also exploring the broader relationship of costume to culture and society through history. The course will comprise visual presentations of the art of each period, especially pertaining to representations of clothing, along with research projects, quizzes and exams.

54-247 Dramaturgy 6: In Company

Intermittent: 9 units
Dramaturgical work in a theatre company extends far beyond individual productions. In this course students get hands-on practice in season planning, writing fundraising text, writing marketing text, and public speaking - all responsibilities that are typically but less visibly part of a dramaturg's job description. This course provides good grounding for a future in artistic leadership. Required for dramaturgy and directing majors; open to non-majors with instructor permission.
Prerequisite: 54-184

54-249 Stagecraft II

Fall: 14 units
Stagecraft II presents advanced shop skills and beginning department head skills for Scenery, Lighting, and Costumes. This course will require additional time during the evening and on weekends. Prerequisites: Stagecraft I (two semesters) OR Instructor Permission
Prerequisites: 54-151 and 54-152 and 54-158

54-250 Introduction to Scenic Design

Spring: 6 units
This course will introduce students to the principles and methods of designing scenery using the development of ideas based on a text.
Prerequisites: 54-169 and 54-232 and 54-172 and 54-231 and 54-171

54-251 Automated Lighting Maintenance

Spring: 2 units
Hands-on exploration of the operation and maintenance of equipment that falls into the category of automated lighting.

54-252 Introduction to Lighting Design

Spring: 6 units
Students explore the physical properties of light in various design applications and develop a process of storytelling that involves analysis, research, exploration, questioning, problem solving and implementation of a successful design product. Prerequisite: Design for the Stage, or instructor permission.
Prerequisites: 54-231 and 54-232

54-254 Dramaturgy 7: New Play Development

Spring: 6 units
This course will serve as an intensive workshop for new plays in collaboration for playwrights and dramaturgs. Playwrights will present pages from a piece they are currently developing, utilizing other playwrights and dramaturgs as their "cast" for the purpose of hearing the play aloud. The dramaturg paired with each playwright will facilitate a feedback session, built from conversation with the playwright, to elicit feedback from those in class that will aid in the creation of future drafts.

54-255 New Play Collaboration for Actors

Fall: 1 unit
TBA
Prerequisite: 54-101

54-256 Dramaturgy 4: New Play Dramaturgy

Intermittent: 9 units
This course focuses on the dramaturg's collaborative relationship with a playwright during the creation of a new play. During the first mini, dramaturgs work on close reading of multiple drafts of a new play, tracking changes and assessing their impact, and developing healthy collaborative processes. During the second mini, playwrights join the course; each dramaturg is matched with a playwright and puts those new skills into practice. Required for dramaturgy majors; no non-majors will be admitted to this course in fall 2020.
Prerequisites: 54-184 and 54-109

54-257 Directing: Production II

Fall: 6 units
Assignments as stage manager or assistant director.

54-258 Directing: Production II

Spring: 6 units
Assignments as stage manager or assistant director for the Rauh Studio and Chosky Theatres.

54-264 Welding

Fall and Spring: 4 units
An introduction to the two most commonly used welding processes used in the entertainment industry. GMAW (MIG), and GTAW (TIG). Welding safety, equipment setup and basic welding techniques will be covered. This is a required course for Drama Technical Direction majors. Open to non-majors if space is available.

54-265 Advanced Fabrication 1

Fall: 6 units
This class sets forth to gain a comprehensive understanding of the various tools found in a well-equipped fabrication shop . Shop safety will be emphasized at all times and rigorously promoted per tool. Understanding the differences between tools and when to choose each will be a constant theme. Exploring the various ways of achieving a certain result but with different tools will be a recurring theme. Since most shops use tools for multiple applications, understanding how various materials relate to various tools will be discussed in detail. For TDs only. The first task will be to do an overview of all of the common tools used for woodworking and metalworking. Then we will go through the shop tool-by-tool and make sure everyone understands what the tool was designed for, how it is used, and how it may be utilized for alternative uses.

54-266 Stage Management: Cue Lab

Fall and Spring: 4 units
Required for Production Management / Stage Management majors. Practical experience in cue calling from a variety of sources and with various tools and methods.

54-267 Conceptual Sound Design

Fall: 9 units
Students explore the unique qualities of audio as a design element and the development of a design process through script analysis. Emphasis on the creative application and utilization of the studio in sound shaping and soundscape design. PREREQUISITE: 54-166 Introduction To Sound Design for Theater, 54-231 Design For The Stage. Drama majors have priority, however this course is also open to Music Technology majors and minors, or with permission of instructor.
Prerequisite: 54-166

54-268 Collaborations in Organized Sound

Fall: 3 units
Both music and sound design are defined by the presence of a human hand in the organization of sound. This course explores what lies at the intersection of music, technology and sound design, as well as the challenge of writing for an experiential, time-based art. Using compositional and dramatic writing techniques in conjunction with the creative application and utilization of studio techniques, field recording, editing and sound manipulation, the student will explore this interstitial landscape. Drama majors have priority, however this course is also open to Music Technology majors and minors, or with permission of instructor.
Prerequisites: 54-166 and 54-267

54-269 Studiocraft II

Spring: 3 units
A continuation of 169/170, this course introduces applied drafting practices, perspective drafting, 3D CAD modeling, model building, and other graphical skills. Prerequisites: 54169 and 54170 OR Instructor Permission
Prerequisites: 54-171 and 54-172

54-271 Technical Management

Fall: 6 units
Required for all sophomore Design and PTM students. This class establishes a set of standards for creative project management and introduces students to several software packages that can be utilized within these tasks.
Prerequisites: 54-158 and 54-157

54-272 Scenic Fabrication and Installation

Spring: 3 units
The Scenic Fabrication and amp; Installation course consolidates and builds upon material presented in the first semester of Basic PTM and in the three semesters of Stagecraft class. Whether they intend to pursue careers as technicians, engineers, or managers students much understand how scenery is built and what is involved in the assembly of the scenery in the theatre. Throughout the semester students will explore the materials and equipment used by all kinds of professionals in the fabrication industry. Through this exploration students will become conversant with the kinds of properties, and the advantages and disadvantages of many different items. Along with this exploration is a concurrent investigation of entertainment industry accidents. This material is valuable in how it contextualizes the kind of work students will be involved in, and helps to drive home the very real consequences of errors pertaining to scenery. In the classroom and in lab students in this course will develop their knowledge and processes for building scenery. The course has three basic units. The beginning of the semester focuses on building materials and on tool use. Through the center of the semester course material focuses on traditional scenery practices. The end of the semester material addresses rigging systems and scenery rigging practices. Laboratory assignments tied to this course will consist of carpentry assignments in the shop and carpentry and rigging assignments during load in. Occasionally students pursuing a more customized path may have lab assignments in the paint department in the shop and in the electrics department during install. All students may receive apprentice assignments in the scenery office.

54-273 Technical Direction I

Fall: 6 units
This course is an exploration of techniques and practices of the Technical Director. The class has three main components: classroom presentation of School of Drama production technical direction process, classroom lectures centering on TD process, and project work. Over the course of the semester, students will work on two productions as paper projects. This is an opportunity to have a somewhat less stressful pass through a show, completing estimates, schedules, and drawings designed to help establish a professional foundation for the student as a technical director. All of the course components run concurrently. Prerequisites: 54272 or Instructor Permission
Prerequisites: 54-158 or 54-272

54-274 Seminar in Costume Management

Fall: 4 units
This mini course focuses on the fundamentals of organizational paperwork surrounding costume production and basic operational protocol. The evolution of this paperwork and its usefulness in multiple professional applications is covered.

54-275 History of Sound Design

Intermittent: 3 units
The history of the use of sound in theater from the Greeks to current day including study of the development of the art, significant practitioners and landmark productions.

54-277 Negotiation and Conflict Management

Fall: 3 units
This class is a focused exploration of the process of negotiating, both formally and everyday. We will examine interactions on all levels and environments, with an evaluation of tactics, strategies and the measure of success. From there, the class expands into the nature of conflicts and the manager's role in identifying and confronting them. Throughout the class, we hope to find solutions to implement in our lives and work. In-class exercises and roleplay will be a fundamental part of class activity.

54-278 Stage Management I

Spring: 6 units
This class introduces the student to the work of a stage manager on a theatrical production. Students learn the functions and responsibilities of the stage manager. Also covered: blocking notation, cue organization, rehearsal reports and AEA rules and regulations.

54-279 Embedded Electronics

Fall: 3 units
TBD

54-281 Foundations of Drama II

Fall and Spring: 6 units
In this course students build on the skills of Foundations I to develop acumen in targeted research in support of production. The students learn the "circles of knowledge" technique to provide evidentiary arguments concerning a play script, its author, the historical contexts in which it was written, the theoretical frameworks that may be applied to its interpretations, its production history, and what knowledge is needed to bring its themes to relevance in a modern production. As in Foundations I, there is a great deal of exposure to significant texts, both artistic and philosophical, from theatre history. Registration for this course is limited to Drama majors. All other majors must request the instructor's permission.
Prerequisites: 54-178 or 54-177

54-284 Fundamentals of Directing

Fall: 6 units
Fundamentals of Directing is a fall-semester course for Drama Design and PTM sophomores. It is an introductory course that examines some of the basic tools of the director. Emphasis is completely on theatrical work although some elements are applicable to television and film.

54-285 Alexander Technique Tutorials

Fall and Spring: 1.5 units
Half-hour tutorials, individually scheduled per student. Optional for Acting and Musical Theater students.
Prerequisite: 54-101

54-287 Introduction to Lighting Design Skills

Spring: 3 units
Students will gain the basic skills and practical experience to use the lighting industry's primary software programs: Vectorworks and Lightwright. The class will be seminar based and allow focused opportunity to acquire the skills to execute some of the assignments in the Introduction to Lighting Design course. This course must be taken simultaneously with Introduction to Lighting Design (54-252).

54-290 IDeATe: Movement for Animators

Fall and Spring: 4 units
Movement serves as a basis for communication and visual storytelling. This course will provide actual physical movement training so that you may better understand its implications and applications for technology-based usage and your own engagement in the creative process with others. Playful participation, observation, and discussion will allow you to consider how to apply physical movement and movement theory in the areas of Animation and Special Effects, Motion Capture, Game Design, and other technology practices and research. Drawing from a number of methodologies you will explore how the variances of Time, Space, Weight, and Energy affect communication, storytelling, character development and narrative structure. We will examine the ways in which movement conveys psychological intent and emotion. This course is designed for students who may range from having no prior movement training experience to those who have some background in sports, dance or theatrical movement.

54-294 Make-Up for Performers

Spring: 2 units
PREREQUISITE: Acting/MT major in the School of Drama. Basic techniques of stage make-up and their adaptation to theatrical styles.
Prerequisite: 54-102

54-295 Advanced Fabrication II

Fall: 6 units
Continuation of Ad Fab. For Drama PTM-TD only.

54-297 VMD Systems Studio

Spring: 9 units
This course is designed to augment the conceptual background and technical skills of First year Graduate students and newly declared VMD Sophomores, and others interested in learning about media design for theater and installations. The course reviews foundational readings about media, technology and society and explores the skills used in contemporary media work. Through real-world examples, building custom media servers, experimenting with materials and software, rigging multiple types of display systems and visiting artists - students will learn the best practices for bringing their designs to life. A great deal of technical information will be covered including; video compression formats, projector optics, cueing software, projection mapping and amp; custom surfaces, media servers both custom and professional, networking and control protocols, live camera systems, and stage rigging for projection systems. The class will give students a clearer perspective of the field and help them plan a fulfilling course of study, based on their goals and interests. Class projects range from presentations of research to building media installations over at Studio 201. Required for new VMD Sophomores, 1st Year VMD Grads; open to IDeATe and BXA students; others accepted up to class limit.
Prerequisites: 54-232 and 54-231

54-299 Dramaturgy Production:Assistant

Fall and Spring: 9 units
For Dramaturgy majors.

54-300 Dramaturgy Research Hours

Fall and Spring: 6 units
For Dramaturgy majors.

54-301 Acting III

Fall
This is a two-semester course in Acting for Third-Year Actors and amp; MTs who will explore performance within directed structure in various non-Fourth-Wall forms of Theatre including: Greek Tragedy, the Greek Chorus, Moliere Comedy and amp; Brecht. This is not a course that will aspire to provide any "correct" way to play various "styles". Rather, it is a course in which to acquire new tools and amp; perspectives when working in new theatrical worlds. Goals include: to find the appropriate level of external expression to meet the demands of the particular text and amp; its directed world, and amp; to "fill the Form" believably and amp; passionately; to make active choices within a directed framework; to learn to work within industry standards; to learn the nature of the actor's "homework" in a directed framework; to include the Audience in the work.
Prerequisites: 54-201 and 54-202

54-302 Acting III

Spring: 5 units
This is a two-semester course in Acting for Third-Year Actors and amp; MTs who will explore performance within directed structure in various non-Fourth-Wall forms of Theatre including: Greek Tragedy. This is not a course that will aspire to provide any "correct" way to play various "styles". Rather, it is a course in which to acquire new tools and amp; perspectives when working in new theatrical worlds. Goals include: to find the appropriate level of external expression to meet the demands of the particular text and amp; its directed world, and amp; to "fill the Form" believably and amp; passionately; to make active choices within a directed framework; to learn to work within industry standards; to learn the nature of the actor's "homework" in a directed framework; to include the Audience in the work.
Prerequisite: 54-301

54-305 Voice for the Stage III

Fall: 5 units
Students explore voice work and various methods in more depth and Alexander alignment/awareness work to enhance vocal freedom and full body support of the voice. Areas include: breath support, vocal release, developing freedom in resonating areas, clarity in articulators, building range and stamina. Emphasis is placed on integration of methods with speaking of text. Writing projects are sometimes explored as a way to free the voice creatively and imaginatively. Voice/Alexander 1 is a pre-requisite to registering in this course.
Prerequisites: 54-105 and 54-106

54-306 Voice for the Stage III

Spring: 5 units
Students explore voice work and various methods in more depth and Alexander alignment/awareness work to enhance vocal freedom and full body support of the voice. Areas include: breath support, vocal release, developing freedom in resonating areas, clarity in articulators, building range and stamina. Emphasis is placed on integration of methods with speaking of text. Writing projects are sometimes explored as a way to free the voice creatively and imaginatively. Voice/Alexander 1 is a pre-requisite to registering in this course.
Prerequisites: 54-105 and 54-106 and 54-305

54-307 Movement III

Fall: 5 units
This course is designed to provide students with an introduction to the actor training method of Tadashi Suzuki in conjunction with a more advanced investigation of the Viewpoints actor training gained in the student's first year. This course examines and explores the use of language and the human body as an expressive artistic instrument. Concepts of the body in relation to Time, Space, and Energy will be explored. This is a studio course in which learning is experiential.
Prerequisites: 54-207 and 54-208

54-308 Movement III

Spring: 5 units
This course is designed to expand the student's movement skills to include the basic principles and techniques of unarmed stage combat and an introduction to weapons fighting. As a studio course, activities will consist of learning and performing physical techniques, reading materials pertaining to the subject matter, viewing filmed examples of work, and giving performance presentations.
Prerequisites: 54-207 and 54-208

54-309 Speech III

Fall: 4 units
TBA

54-310 Dialects and Accents

Spring: 6 units
For School of Drama Acting/MT students only.

54-311 Rehearsal and Performance III

Fall
Performance training through projects at different levels of difficulty and staging, directed by students and presented in the studio theatre. The actor has the opportunity to put into practice with his/her peers, in a creative and experimental atmosphere, the principles and techniques developed in the classroom.
Prerequisites: 54-201 and 54-202

54-312 Rehearsal and Performance III

Spring
Performance training through projects at different levels of difficulty and staging, directed by students and presented in the studio theatre. The actor has the opportunity to put into practice with his/her peers, in a creative and experimental atmosphere, the principles and techniques developed in the classroom. Note: Tues or Thurs time used as needed for performance critiques.
Prerequisites: 54-201 and 54-202

54-313 Dance III: Expand the Dynamics of Dance Technique

Fall: 3 units
Intermediate ballet. This course is dedicated to honing technical skills, expanding the classical dance vocabulary to the next level of difficulty, and addressing issues of strength, stamina, and endurance. Course closed: Only for Music Theatre majors in Drama. Prerequisite: Permission of instructor
Prerequisites: 54-205 and 54-206

54-314 Dance III: Expand Dynamic of Dance Technique

Spring: 3 units
Intermediate ballet. This course continues to hone technical skills, expand the classical dance vocabulary to the next level of difficulty, and address issues of strength, stamina, and endurance. Course closed: Only for Music Theatre majors in Drama. Prerequisite: 54-313 and Permission of instructor
Prerequisite: 54-313

54-315 Jazz III

Fall: 2 units
This course is to expand the versatility of the student dancer to master more complex exercises, in dynamics, direction and rhythm using Jazz styles examined by decades. Understanding the 20th century historical background of the 20's, 30's 40's, 50's 60's and 70's. Course closed: Only for Music Theatre majors in Drama. Prerequisite: Permission of instructor
Prerequisites: 54-217 and 54-218

54-316 Jazz III

Spring: 2 units
This course continues to expand the versatility of the student dancer to master more complex exercises, in dynamics, direction and rhythm using Jazz styles examined by decades. Understanding the 20th century historical background of the 20's, 30's 40's, 50's 60's and 70's. Course closed: Only for Music Theatre majors in Drama.
Prerequisite: 54-315

54-317 Singing for Actors III

Fall: 2 units
The students have a class voice experience which includes a physical and vocal warm-up and discussion and practice of healthy singing technique. There is group and individual rehearsal of potential audition and performance material. Toward the end of the term, there are weekly opportunities to perform in public, thus preparing for auditions.
Prerequisites: 54-201 and 54-202

54-318 Singing for Actors III

Spring: 2 units
The students have a class voice experience which includes a physical and vocal warm-up and discussion and practice of healthy singing technique. There is group and individual rehearsal of potential audition and performance material. Toward the end of the term, there are weekly opportunities to perform in public, thus preparing for auditions.
Prerequisites: 54-201 and 54-202

54-319 Cabaret

Fall: 6 units
The Art of Cabaret: Explores the use of Stories and Song to communicate life experiences within an intimate setting, breaking down the invisible fourth wall for honest communication. The course includes a section on the use of the microphone for singers. This Study produces two Cabarets containing Material on a chosen Theme to provide hands-on Song Expression in a public forum.
Prerequisite: 54-220

54-320 Costume Forum

Fall: 1 unit
Costume Majors

54-321 Acting III for Directors

Fall: 9 units
An examination of various directing styles with particular attention to: verse forms including Greek and Elizabethan, comedy/ farce texts and Early 20th century styles including Ibsen and Shaw. On occasion, guest directors for our main-stage productions will be engaged to teach the style of the production that they are presently working on. Alternately, there is the possibility of this semester being used for an applied internship with a major producing organization.
Prerequisites: 54-201 and 54-101

54-322 Directing III: INTRODUCTION TO TV & FILM DIRECTING

Fall: 9 units
An intensive introduction to directing with a camera in narrative film and episodic television for third year undergraduate directing and dramaturgy students. Students learn how to prepare for a camera shoot including breaking down a script, camera terminology, shot types and what can be accomplished, how to make a shot lists, visual style and how to express it. Students learn shot progression in the scene and point-of-view. This class will also include working with actors where we use a camera to film them under strict COVID guidelines.

54-323 Tap III - Expand Percussive Rhythms

Fall: 2 units
This course expands tap vocabulary and clear precision of execution through moderately difficult and extended combinations. Course closed: Only for Music Theatre majors in Drama. Prerequisite: Permission of instructor
Prerequisites: 54-223 and 54-224

54-324 Tap III: Expand Percussive Rhythms

Spring: 2 units
This course continues to expand tap vocabulary and clear precision of execution through moderately difficult and extended combinations. Course closed: Only for Music Theatre majors in Drama. Prerequisite: 54-323 and Permission of instructor
Prerequisite: 54-323

54-325 Actor Dance III

Fall: 2 units
This course uses basic and fundamental contemporary Jazz styles, i.e. Latin, Blues, Lyric, African, to technically train the body using isolations and rhythmic patterns. Course closed: Only for Acting majors in Drama. Prerequisite: Permission of instructor
Prerequisites: 54-201 and 54-202

54-326 Actor Dance III

Spring: 2 units
This course continues to use basic and fundamental contemporary Jazz styles, i.e. Latin, Blues, Lyric, African, to technically train the body using isolations and rhythmic patterns. Course closed: Only for Acting majors in Drama. Prerequisite: 54-325 and Permission of instructor
Prerequisites: 54-201 and 54-202

54-327 Auditioning for TV/Film

Fall: 2 units
An optional course for Junior Acting and Music Theatre majors.
Prerequisite: 54-202

54-328 Advanced Digital Sound Design Skills

Fall: 9 units
Sound Design Majors ONLY. Advanced sound creation and manipulation through student designed and constructed software and hardware. Prerequisite: Conceptual Sound Design I.
Prerequisite: 54-267

54-329 Junior Theatrical Voice

Spring: 2 units
Missing Course Description - please contact the teaching department.

54-330 Introduction to Stage Management

Spring: 6 units
This course is intended to provide students an opening to the knowledge and skills of the professional stage manager. It will also illuminate the qualities of a good stage manager specific to personality and human interaction. Within this course we will examine the role of the stage manager throughout the full scope of creating a production, including preparatory work, rehearsal period, technical rehearsal, performance and closing.

54-331 Scenic Design: Explorations

Fall: 9 units
Students will spend the year in an exciting and intensive exploration of the process of Scene Design as well as an examination of the nature of creativity and storytelling. Students will also engage extensively in the skills a professional Scene Designer requires, such as drafting, drawing, model making, painting and general collaborative skills. Students will be expected to deal with in-depth research, scriptual examinations, careful arrangements of space, composition and groundplan, conceptual structure, real life obstacles and the elements of a successful final project. By the end of this course, students will have improved their overall design skills, have some projects they can include in their portfolio and have created new routes toward their creativity. (pre-req, intro to Scene Design)

54-332 Scenic Design: Boot Camp

Spring: 9 units
A rapid-fire design course for scenic design majors. This course offers the students the opportunity to work on six projects over the course of the semester. These projects may include contemporary, classical and non-linear plays, as well as TV workshop and a new plays collaboration with dramatic writing students. Co-taught by Scenic Design faculty.
Prerequisite: 54-250

54-333 Production Personnel Management

Fall: 6 units
Study of the management of production personnel for live theatrical productions. In depth analysis of union contracts from a management perspective: AEA, IATSE, USA. Projects in scheduling and budgeting based on those contracts. Study of hiring, evaluating, and retaining a quality staff. Examination of the role of safety protocols in production. The Course concentrates on the relationship between the Production Manager and all of the personnel that one comes in contact with. For Senior SMPM and TD ONLY or with instructor permission.

54-334 Production Resource Management

Spring: 6 units
This course examines the management of resources for the production of live theatrical productions. We start with analysis of scripts, to find the foundation for resource allocation. Then we move on to study the allocating two of the largest production resources: time and money. A significant exploration of the tracking of time and money extends throughout the course, with half of the class sessions taking place in a computer cluster, where we concentrate on advanced application of Excel, Access, and specialized calendar software.

54-335 Auditioning for the Stage

Spring: 2 units
An optional course for Junior Acting and Music Theatre majors.

54-336 Musical Theater History

Intermittent: 6 units
This course is a survey of musical comedy and musical theatre performances throughout history. Often considered a quintessential American theatrical form, we will also consider what "musical theatre" or "musical drama" means beyond the borders of the United States. The course will primarily focus in the time frame of 1860-present. We will examine the historical background, development and evolution of form, as well as impact and proliferation of this performance style. The course will involve lecture-based, discussion-based, and project-based styles of engagement. **No previous knowledge of or practice of "musical theatre" is necessary to succeed in this course. Open to non-majors.

54-337 Introduction to Lighting Technology

Fall: 6 units
Introduction to Entertainment Lighting Technology provides students with an overview of lighting equipment and software used in entertainment production. Topics include automated fixtures, console programming and pre-visualization software.

54-338 New Works Collaboration

Fall and Spring: 3 units
TBA

54-339 Stage Management Seminar

Fall and Summer: 3 units
This class provides stage managers an opportunity to participate in in-depth discussion about the production process. Specific issues related to CMU productions and troubleshooting problems are a particular focus. The class also presents guest speakers on related topics and will work on longer-term projects as needed.

54-340 Coding & Control for Theatrical Sound

Fall: 9 units
This course will explore coding techniques, show control, networking and software applications within the context of theatrical sound design and amp; engineering. Pre-requisites 54267, 54166 and amp; 54389 (or permission of instructor.
Prerequisites: 54-267 and 54-166 and 54-389

54-341 Fundamentals of Costume Design

Fall: 9 units
Multiple studio projects comprise this one semester course that focuses on the principals and elements of design, including color theory, as they relate to Costume Design. Projects focus on the empowerment and development of each student's individual imagination. PRE-REQUISITE: Declared Costume Design Major in School of Drama. All others: Portfolio Review and special permission of teacher required. Drawing For The Theatrical Designer and Figure Drawing may be taken concurrently. FOR: First semester Graduate Costume Design and Costume Production Students, First semester Junior Costume Majors.
Prerequisite: 54-162

54-342 Costume Design for TV and Film

Spring: 7 units
A course that explores the aesthetic and technical processes of designing costumes for the screen. The course introduces film-specific practical skills including the fundamentals of analyzing and breaking down screenplays for costume design, what design means during the pre-production and shooting phases of a production, and the aesthetic and technical differences of designing for the camera's eye compared to designing for the human eye. The course will consist of lectures, visual presentations, including viewing of films that illustrate the processes described in class, script break-down assignments, and design process projects. PRE-REQUISITE: Design/PTM Costume major. All others: Portfolio Review and special permission of teacher required. FOR: Second year Graduate Costume Design majors and Costume Design students.

54-343 Lighting Design Skills 2

Fall: 3 units
TBA
Prerequisite: 54-367

54-346 Introduction to Costume Construction

Spring: 6 units
This sophomore level course is designed to provide an intermediate level of training in the area of clothing construction. Students will learn how to read patterns, prepare and cut fabric appropriately for construction purposes, and complete a garment employing necessary finishing techniques. Additionally, students will be exposed to the rudimentary skills necessary for basic flat patterning and begin the process of project time management and comprehension of product value.
Prerequisites: 54-231 and 54-232

54-347 Sound Workshops

Fall: 3 units
TBA
Prerequisite: 54-166

54-349 Automated Lighting Technology

Spring: 9 units
Automated lighting equipment is explored, with a concentration in programming techniques on advanced lighting control consoles.
Prerequisite: 54-369

54-350 Scenic Design Forum

Fall and Summer: 1 unit
Required weekly meeting of all Scenic Designers.

54-351 Theatrical Lighting Design

Fall: 9 units
The student's ability to analyze and translate information in the script to descriptive stage pictures is developed in a more in-depth process. Verbal, written and visual communication of ideas is emphasized and explored through texts and lab work. Issues of collaboration with the director and other members of the design team are discussed as part of the design process. Prerequisites: 54252
Prerequisite: 54-252

54-352 Musical and Opera Lighting Design

Spring: 9 units
Through hands-on lab exercises and preparation of full lighting design plots, students will study lighting design for Musical Theater and Opera. The class will learn to visually analyze the emotional content of music, explore the various forms of musical performance, learn how to develop a design process, create focus in a large-scale space, and strategies for implementing a design.
Prerequisite: 54-351

54-353 Structural Design I

Fall: 9 units
Required for all senior undergraduate Technical Direction students. A concentrated training in Structural Design specifically developed for the theater technician. This course teaches the process of Allowable Stress Design for the engineering of scenic structures in wood and steel. Drama majors only, or with instructor permission.

54-354 Structural Design II

Spring: 9 units
Required for all senior undergraduate Technical Direction students. Upon completion of this two-semester sequence, students are familiar with beam and column design/specification, truss design, tensile systems and structural connections.
Prerequisite: 54-353

54-355 30 Hour OSHA

Intermittent: 2 units
For Production Technology and amp; Management majors.

54-356 Production Prep: Lighting Production

Fall and Spring
Production Preparation is a required course and is a core component of the curriculum for all drama production and design students. The production experience provides students with experience in the following areas: production management, stage management, production run work, stage operations, design, lighting, sound, costume construction, prop construction, scenery construction, video and media, and scenic painting. Fully participating in these experiences will facilitate students' future success in the School of Drama as well as in the profession.

54-357 Directing: Production III JPP

Fall: 12 units
Assignments as stage manager or assistant director.

54-359 Introduction to Show Networking

Fall: 3 units
Introduction to Show Networking explores the integration of network structures and methods into entertainment production. Presented as two remote sessions (January 19 and February 16, 4-5:20 PM) and one in-person workshop (1/23, 9 AM-4 PM), the course will utilize readings and individual study as preparation for a series of projects to demonstrate networking techniques as applicable in the field of production technology.
Prerequisite: 54-249

54-360 Leadership Workshop: Ethics & Innovation

Intermittent: 6 units
This course will be an exploration of both innovative strategies and the ethics of leadership within the performing arts. It will build on the management principles covered in foundational courses and is designed to offer the student an approach to leadership development that is tailored to the individuals strengths and needs as well as their role within theatrical organizations. For PTM students only or with permission from the instructor.
Prerequisite: 54-333

54-361 Production Preparation

Fall and Spring
Participation in School of Drama productions in design or production roles.

54-362 Anti-Racist & Equitable Practices in Theater

Fall: 6 units
This course will be a series of workshops delivered in a hybrid format (partially online, partially in person, some independent work) exploring the topics of race and theatre with a primary focus on the US. Students will cover topics such as race and racism, creating welcoming theatre spaces, scene selections, tropes, and strategies for cultural competency and a survey of artists and theatres who have done culturally competent work. Practical skills around creating mission and values, cultural aesthetics, and advocacy will be covered. Students will practice research and critical analysis of various theatre systems as well as creative problem solving. Classes will not meet every week but the first day of classes August 30 and 31 will be in person where a schedule and syllabus will outline the semester.

54-363 Dramaturgy 4: Devising

All Semesters: 9 units
Dramaturgy students only. Others by permission. In this class, students will: - gain an introduction to the history and practice of devised and amp; documentary theatre - explore the dramaturg's role in devising theatre - investigate various methods for creating devised and amp; documentary theatre - learn techniques for developing theatre from source material - create original devised pieces in collaboration with other students
Prerequisites: 54-184 and 54-109

54-364 Dramaturgy 7 - Expo Prep

Intermittent: 9 units
For Dramaturgy majors.
Prerequisite: 54-363

54-365 Machine Design I

Spring: 9 units
Required for all senior undergraduate Technical Direction students. In this course, concepts from Physics of Stage Machinery are applied to the specification, selection, design and assembly of real-world mechanical components for the realization of winches, turntables, wagons and lifts for theatrical use. Drama majors only, or with instructor permission.
Prerequisite: 54-366

54-366 Physics of Stage Machinery

Fall: 9 units
This class teaches the basic physics of dynamic mechanical systems, specifically in the context of lifts, winches, turntables and wagons used in theatrical production. Material covered consists of Newtonian Dynamics, elementary mechanics, and fluid power. Required for all junior undergraduate PTM students. Drama majors only, or instructor permission.

54-367 Lighting Design Skills

Fall: 6 units
Students will concentrate on developing the skills necessary for lighting designers to successfully implement their designs in the theatre. Content includes communication, CAD programs, paperwork, focusing the show, programming conventional and moving light consoles, cue writing and expectations and responsibilities of the design assistant. Prerequisite: 54252
Corequisite: 54351
Prerequisite: 54-252

54-368 Introduction to Lighting Management

Spring: 6 units
Lighting Management I is an overview of the management process within a theatrical lighting department. Topics covered include communication tools, paperwork and physical resources used by department heads to facilitate lighting designs, as well as other duties performed within that role.
Prerequisite: 54-249

54-369 Lighting Management II

Spring: 4 units
Lighting Management II continues the investigation of the role of the department head within a theatrical lighting department, concentrating on skills needed to perform the role within the School of Drama.

54-370 Dramaturgical Sensibilities

Spring: 3 units
In this course, dramaturgy majors will meet with professionals in the field who have used a dramaturgical sensiblity to build careers in "dramaturgy-adjacent" fields.

54-371 Production Preparation

Fall
Participation in School of Drama productions in design or production roles

54-372 Theatre for the Ear

Spring: 6 units
Survey of aural storytelling with technology focusing on forms with no visual component. Topics include the history of radio drama to present day, radio sound art, cut-up and tape manipulation, comedy records and podcast dramas. Prerequisites: 54-166 Introduction To Sound Design, 54-267 Conceptual Sound Design 1 Restrictions: The course is open to sound design majors or with permission of the instructor.

54-373 Draping Fundamentals

Fall: 3 units
Draping Fundamentals is a half-semester introduction to the arena of the costume draper. This course illustrates what the draper's role is in effectively spearheading garment production for the performing arts, emphasizing the collaboration skills needed to propel a design from page to stage. The course instills a strong foundation in pattern development skills through the use of the dress or suit stand. Additional skills such as application of research, fitting procedures and protocol, pattern manipulations and refinements and complete construction plans are explored. This class provides tangential learning through a thorough investigation of sculptural and spatial relationships, emphasis on strategic planning, development of fine motor skills, and exposure to a broad spectrum of materials and methods that can be adapted to other purposes.

54-374 Musical Theater Audition

Spring: 5 units
Missing Course Description - please contact the teaching department.

54-375 IDeATe: Robotics for Creative Practice

Fall: 9 units
Robots come in all shapes and sizes: it is the integration of software and hardware that can make any machine surprisingly animate. This project-oriented course brings art and engineering together to build performance systems using embodied behavior as a creative medium. Students learn skills for designing, constructing and programming automated systems for storytelling and human interaction, then explore the results through exhibition and performance. Technical topics include programmed motion control, pneumatic machine design, closed-loop feedback systems, machine choreography, and human-robot interaction. Discussion topics include contemporary kinetic sculpture and animatronics. This interdisciplinary course is part of IDeATe Physical Computing but is open to any student.
Prerequisites: 60-210 or 99-361 or 15-112 or 15-104 or 60-212 or 15-110

54-376 Entertainment Rigging

Spring: 3 units
This course is a survey of the techniques and practices of theatrical rigging. The course has two main components: permanently installed rigging systems typically found in theatres, and background and technical information concerning the components typically used for stage rigging. Discussion topics include selection criteria for line, hardware, and terminations stressing entertainment industry standards, workplace safety and common industry misconceptions. Time permitting the course will shift from a general discussion of components to their assembly into custom rigging systems and amp; solutions. Instructor's permission only.

54-377 Production Composition Studio

All Semesters: 3 units
This course is a laboratory style studio class. It is designed to support the student through the process of composing music for theatrical and amp; film productions and projects. Students will be required to bring ongoing creative work materials to class.
Prerequisites: 54-389 and 54-390

54-378 Technical Direction II

Spring: 6 units
This course is an exploration of techniques and practices of Technical Designers. The class has four main components: an exploration of the types of strategies used by Technical Designers to arrive at solutions, building an expert vocabulary for discussion of technical design issues, development of actual technical solutions, on paper, in discussion, and in the shop, discussion of any pertinent technical issues for any of the school productions while in development.
Prerequisite: 54-273

54-379 Captured Storytelling

Fall: 7 units
In this course we will consider the differences between traditional live storytelling and stories that are captured to be viewed remotely or at a later date. Using the lens as the proscenium, you control how your audience experiences the story. How do you prepare for that? How does the lens change the way we design? We will talk with and explore the work of industry professionals such as directors, cinematographers, production designers, editors, and costume designers. Hands on, we will storyboard and shoot our own stories.

54-380 Music Reading for Production

Fall: 3 units
This class gives the basics of music theory, musical terminology and score reading. Students focus on the difference in various musical scores, ie. piano/vocal, full, hand written scores. Students are guided in classroom listening which a wide variety of music including, opera, musical theatre, ballet, and choral/orchestra works.

54-381 Special Topics: Feminist Theatre

Fall and Spring: 6 units
Every semester, the School of Drama offer seminars on special topics that investigate some aspect of theatre history, dramatic literature, dramatic theory, or a particular author, period, or genre. Feminist Theatre: Theory and amp; Practice of Cultivating a Feminist Theatre: This course investigates the relationship between feminist theory and performance. The syllabus is grounded in works that deal specifically and overtly with issues of gender, sexuality, race and class. We will pay particular attention to the ways in which these issues have shaped feminist thought and the process of canonization. Our study will focus on the following questions: Is there a feminist dramaturgy? Is there a feminist dramatic tradition? How has feminist performance been produced, staged, and received throughout history? What is feminist theater and has it served as an agent for social change? We will read representative feminist plays by writers of diverse backgrounds, using class discussion to analyze these dramatic texts alongside feminist theory. Playwrights whose work we'll investigate may include: Suzan-Lori Parks, Alice Birch, debbie tucker green, Mar and #237;a Irene Forn and #233;s, Sarah Ruhl, Caryl Churchill, Young Jean Lee, Lillian Hellman, Sophie Treadwell, Alice Childress, and Franca Rame. Feminist theorists/writers whose work we'll read alongside these plays may include: Audre Lorde, bell hooks, Silvia Fedirici, Lisa M. Anderson, Patricia Hill Collins, Kim Solga, Laura Mulvey, and Jill Dolan.

54-382 Anti-Racist Theater: In Context

Fall: 4.5 units
TBD

54-383 Introduction to Digital Media

Fall: 9 units
Software Covered: AutoCAD, Photoshop, Illustrator, InDesign, Sketchup, Vray for Sketchup Concepts Covered: 2D Graphics, Architectural Drafting, 3D Modeling and amp; Rendering, Hybrid Representation Limited to Drama students: Scenic Design Juniors, 1st Year Graduate Students

54-385 Automated Lighting Rig Engineering

Spring: 6 units
Students continue to develop technical drawing and engineering skills while completing the decision-making process for the implementation of a concert lighting rig.

54-386 Scenic Design Skills: 3D Model Making

Spring: 4 units
In this mini students explore a variety of three-dimensional media techniques as they learn to build models for the Scenic Designer. Students will investigate many aspects of model-making, from basic structural ideas to complex organic and architectural forms, furniture, and advanced techniques such as scale painting, soldering and carving. Through these methods, students will develop a better understanding of space and objects in space in the theatre.
Prerequisite: 54-231

54-387 Dramaturgy : Production I

Fall and Spring: 9 units
Working as a production dramaturg for a Horizons Reading or as an assistant dramaturg.

54-389 Composition for Theatrical Sound Design 1

Fall: 9 units
Composition for Theatrical Sound Design 1 This course will concentrate on developing compositional skills for use in theatrical sound design. The full length of this course is designed to take place over two semesters. The rst semester will examine the building blocks of composition such as rhythm, modes, harmony and counterpoint. The second semester will focus on more advanced skills in composition within a theatrical context. Through projects distributed throughout the semester you will practice the skill-based techniques of music notation, orchestration, synthesis, sequencing, and the creation and utilization of sample-based instruments. This course will also cover textual analysis as it applies to both the inspiration for composition and to the more direct challenge of setting music to text.

54-390 Composition for Theatrical Sound Design 2

Spring: 9 units
This course will concentrate on further developing compositional skills for use in theatrical sound design. The full length of this course is designed to take place over two semesters. This is the second semester and builds on compositional techniques such as writing melody, harmony, counterpoint and orchestration techniques. The second semester focuses particularly on more advanced skills in composition within a theatrical context. Through projects distributed throughout the semester students practice the skill-based techniques of music notation, orchestration, synthesis, sequencing, working with instrumentalists and the creation and utilization of sample-based instruments. This course will also cover textual analysis as it applies to both the inspiration for composition and to the more direct challenge of setting music to text.

54-391 Lighting Design for Directors

Fall: 4 units
An exploration of the lighting design process that will provide the tools for stage directors to communicate, collaborate and explore with designers. Students will explore the physical properties of light and the artistic potential of light through script analysis and hands on use of the Light Lab. (For Junior Directing Students)

54-392 Scenic Design Skills: 2D Drawing and Rendering

Spring: 4 units
This mini offers practice in two-dimensional drawing and rendering for the theatre.

54-394 Production Prep: Lorca

Fall and Spring
Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-396 Theatrical Lighting Management

Fall and Spring: 6 units
Theatrical Lighting Management continues the investigation of the role of the department head within a theatrical lighting department, concentrating on skills needed to perform the role within the School of Drama.
Prerequisite: 54-368

54-397 Sound Design For Interactive Environments

Spring: 9 units
This course will examine the process, execution and implementation of sound design for interactive and non-linear storytelling paradigms. Emerging trends in immersive theater, gaming, installation art and multi-media place unique demands on the sound designer both in terms of content and delivery. The student will explore how these demands effect the fundamental processes of design, development of content and flexible delivery systems. Through a combination of directed readings, exploration of current and amp; emerging trends, and project assignments the student will be encouraged to experiment and explore design modes and methodologies that support this flexible method of storytelling.
Prerequisites: 54-267 or 54-268

54-398 Special Topics in Sound Design

Spring: 9 units
A one semester course covering various rotating topics including the history and critical theories of film sound design, the history of sound recording and technology, Foley sound, recording and editing techniques, and 5.1 audio. Prerequisites: 54-166 Introduction To Sound Design for Theater, 54-267 Conceptual Sound Design. Restrictions: The course is open to Drama sound design majors and minors, Music Technology majors and minors or by permission of the instructor.
Prerequisites: 54-267 and 54-166

54-399 Decoding Media

Fall: 9 units
Media technologies are designed to do a lot with very little effort. This creates a problem of abundance for artists trying to use these technologies in creative ways. One can relatively quickly pull images off the internet and project them huge onstage, but what does it mean? Decoding is the term I'm using to help you keep control of your process and create meaningful (not just dazzling) imagery for the stage. The entire theatrical process can be considered as a series of decodings and re-encodings, first decoding the text/idea (by the creative team), re-encoding (the design) and finally decoding by the audience. This class is designed to give students a solid foundation in contemporary media design skills while simultaneously providing an examination of the function of theater historically and the ways media technologies fill those needs today. Early assignments focus on students use of media in their everyday lives, by keeping media journals and bringing in media objects for examination. Later classes focus on taking ideas from this research and applying them in conceptual stage designs for an ancient Greek play and then a controversial adaptation from the 1990's by Sara Kane. Students learn how to go from textual analysis to a visual interpretation and staging with media. The class takes students through the process of initial creative brainstorming, to communication tools (concept sketches, digital renderings, 3D models), onto specifying a design through CAD documentation, projection optics calculations and final design presentations.

54-400 Staging Media- Immersive Edition

Spring: 9 units
Are you interested in learning advanced media design skills and creating a multi-room immersive science-fiction experience? Staging Media is a practical, process-oriented class, focused on building the skills to go from a conceptual design to an actual completed event. This semester will be structured around creating a science fiction themed, immersive experience at the 477 Melwood building off campus. Class projects will explore different kinds of immersion, looking at the spectrum from a really engrossing novel on one end, to the sensory overload of Omega Mart/Meow Wolf, or the sensory "capture" of VR systems on the other. Students will work with different technologies and media systems in ways that support these various levels of audience experience. We will read interviews and learn strategies from immersive theater companies such as Non Zero One, Punchdrunk, Blast Theory and others. And we will also read several short stories, parts of novels, and screen a few films in the Melwood screening room's 4K theater, as research and inspiration. Students will use multiple industry standard software systems as they design and build the experience, including Cinema4D, Vectorworks, TouchDesigner, Max/MSP/Jitter, and Unity/Unreal. Prior experience with some of these tools is preferred, but students will also be exposed to workshops and tutorials, and gain practical experience by learning in a project based manner. Visiting artists from the entertainment industry will open the class to their experiences and professional workflows.

54-401 Through the Lens : Storytelling with the Camera

Fall: 9 units
A unified, cross-disciplinary class focused on the artistic and technical requirements for single-camera storytelling. Students from each discipline will receive theoretical instruction, progress to in-class practicum work, and become an integrated production team on a field film project experience. The idea embraces: a single weekly time-frame for classes across several disciplines, a reintegration of management students; and a retooled Camera Lab class in which actors, writers, designers, managers and directors collaborate. Professional guest artists will be frequent visitors to the classroom and production process. Classes will include topics of universal interest to the larger group as well as discipline specific sessions.

54-402 Through the Lens : Storytelling with the Camera

Spring: 9 units
A unified, cross-disciplinary class focused on the artistic and technical requirements for single-camera storytelling. Students from each discipline will receive theoretical instruction, progress to in-class practicum work, and become an integrated production team on a field film project experience. The idea embraces: a single weekly time-frame for classes across several disciplines, a reintegration of management students; and a retooled Camera Lab class in which actors, writers, designers, managers and directors collaborate. Professional guest artists will be frequent visitors to the classroom and production process. Classes will include topics of universal interest to the larger group as well as discipline specific sessions.
Prerequisite: 54-401

54-403 Actor as Artist

Fall: 6 units
TBD

54-404 Writer's Room Workshop

Fall: 9 units
TBD

54-405 Digital Narratives

Fall: 5 units
This course combines options from the School of Drama in a unique configuration: through working collaboratively across disciplines, students will investigate innovative approaches to contemporary theater and new ways of storytelling. Contemporary techniques for ensemble creation, devising and media integration will be explored through exercises, readings, and viewing of other artist's work. This Fall the course will explore the wide variety of digitally mediated forms for online, remote and distanced work - techniques of collaboration, creation and experiencing of performance focused work. We will pursue multiple techniques for cross-platform storytelling, drawing from students' lived experiences to engage the current political and social milieu via multiple digital and mediated systems. Experimental and devised processes of theater making have long mined the complex relationship between the form and the content of an artwork - how can we do so in pursuit of a critical/political perspective? Students will become familiar with contemporary and historical companies who work this way and through small group in-class workshops create new narrative experiences and share them with the larger class. Through embracing these tools and forms, we utilize the theatrical conversation to engage in artistic discourse to discover new complexities of meaning. We invite students to come explore these possibilities in a spirit of experimentation and group exploration.

54-406 Media Creation Studio I

Fall: 6 units
Missing Course Description - please contact the teaching department.

54-407 Movement IV

Fall: 6 units
Movement IV is a Lecoq-based course that focuses upon the creation of actor generated physical theatre. In contrast to the actor-as-interpreter tradition, class work is completely centered upon the actor-as-creator. All performance material is created by the students themselves. Class work includes solo, duo, and ensemble explorations. Improvisational prompts and various themes will be introduced and explored, resulting in improvised or semi-rehearsed presentations. Potential themes include autobiographical material, topical issues, original music theatre, inspirations from nature, interpretations of art (music/poetry/paintings), mask performance, contrasting characters, clown entrees, etc. A final project or projects will be determined by the class material generated throughout the semester, as well as by student interest. Limited to Acting/MT majors only. Prerequisite Knowledge: Movement I, II, and III
Prerequisites: 54-208 and 54-207

54-408 Drama Directing TBA

Spring: 6 units
TBA

54-409 Theatre Lab for Undergraduates I

Fall
This is a two-semester class which teaches the collaborative process of theatre and #8212; including the role of the living dramatic writer. New scripts are written by graduate dramatic writers, then developed and realized by junior actors, senior dramaturgs graduate and undergraduate directors with the playwright. This work results in 10-minute play scripts, one acts, monologue dramas, and the texts for the MFA Thesis Productions. This class is co-taught by the Acting Dramatic Writing, Dramaturgy and Directing Options.

54-410 Theatre Lab for Undergraduates II

Spring
Theatre Lab is a place to practice collaboration. We will examine and explore the relationships between actor, director, and playwright in working on new plays. The objectives are to prepare students to work collaboratively on new play production as it is practiced in the field, to understand the responsibilities of actor, director, and playwright in work on a new text, and to practice being an outstanding collaborator.

54-411 Rehearsal and Performance IV

Fall: 16 units
Participation outside of class requirements in departmental productions. Putting into practice the techniques acquired over the years of training and exploring the development of a performance played before the public over two weeks.
Prerequisites: 54-312 and 54-311

54-412 Rehearsal and Performance IV

Spring
Participation outside of class requirements in departmental productions. Putting into practice the techniques acquired over the years of training and exploring the development of a performance played before the public over two weeks.
Prerequisites: 54-311 and 54-312

54-413 Showcase

Fall: 6 units
Senior acting class for actors and Mt's who are in good standing and in position to graduate in the Spring. Preparation for the New York and Los Angeles Showcase presentations.
Prerequisites: 54-301 and 54-302

54-414 Showcase

Spring: 9 units
Senior acting class for actors and Mt's who are in good standing and in position to graduate in the Spring. Preparation for the New York and Los Angeles Showcase presentations.
Prerequisites: 54-302 and 54-301

54-415 Broadway Dance Styles

Fall: 5 units
This course is designed to provide the student with a practical and historical knowledge of the dance repertoire in American Musical Theater using the original choreography from prominent Broadway choreographers. Course closed: Only for Music Theatre majors in Drama. Prerequisite: Permission of instructor
Prerequisite: 54-319

54-416 Broadway Styles

Spring: 5 units
This course continues to provide the student with a practical and historical knowledge of the dance repertoire in American Musical Theater using the original choreography from prominent Broadway choreographers. Course closed: Only for Music Theatre majors in Drama.
Prerequisite: 54-319

54-418 Songs for Showcase

Spring: 2 units
Vocal preparation for Senior Showcase presentation.
Prerequisite: 54-500

54-419 Production Prep: TBA 11

Fall and Summer
Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-420 Production Prep: Mary-Kate Olsen

Fall and Spring
Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-421 Production Prep: John Proctor

Fall and Spring
Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-422 Directing IV: Next Steps

Spring: 9 units
TBD

54-423 Production Prep: Alcina (SOM 2)

Fall and Spring
Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-424 Production Prep: Bright New Boise

Fall and Spring
Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-425 Production Prep: Grown Ups

Fall and Spring
Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-426 Production Prep: Mr. Burns

Fall and Spring
Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-428 Production Prep: The Dumb Waiter

Fall and Spring
Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-429 Production Prep: TBA 10

Fall and Spring
Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-430 Production Prep: TBA 9

Fall and Spring
Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-431 Scenography

Fall: 9 units
A core design class between scenic designers, costume designers, media designers, and directors collaborating to create projects on paper. This class allows students to experiment away from the pressure of a realized production. The course encourages students to cross traditional boundaries in their own work and to focus on the idea of world building for their projects. This class often includes guest designers and directors.

54-432 Design for Spaces

Spring: 4.5 units
A1: Design for Live Spaces: Scenic Design is a course that focuses on creating design within the format of live performance. The projects will be varied and will include new works, existing texts and other innovative forms of live design within the community. A2: Design for Screen Spaces: Scenic Design is a course that focuses on design for the screen. The projects may alternate between TV and Film design depending on the year. Industry professionals will be part of the course experience, giving students real-time knowledge. Projects will build towards a portfolio of work for use in the industry. This course focuses on developing the design tools in areas such as: research, collage assembly, model making, storyboards and creation of a short reel amongst other things.

54-433 The Basics of Self-Producing for Theater Artists

Fall and Spring: 6 units
Is self-producing for you, or do you prefer to use other people's resources? Basics of Producing for Theater Artists will introduce the mechanics of getting your work to the spectator while creating a sustainable life as an artist. We'll investigate old models and new platforms to help you find the location and the recipe for your unique mission. We will walk through budgeting, fundraising, marketing, contracts, rights, risks, and the audience of the future. As a final project, you will assemble a package you can hand to a potential funder that explains why your theater is needed to fill a void in the culture, and why no one is better suited to do it.

54-434 Production Prep: New Works

Fall and Spring
Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-435 Production Prep: External Projects

Fall and Spring
Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-436 MT Senior Voice Coaching

Spring: 1 unit
No course description provided.
Prerequisite: 54-500

54-437 Acting IV

Spring: 6 units
Tbd
Prerequisites: 54-302 and 54-301

54-438 Acting IV-Improv

Spring: 3 units
Introduces students to Comedy Improv performance; gives students an improv vocabulary; increases students freedom on stage; stimulates students sense of play; and increases students awareness of rhythm/timing/build/fall/recovery.
Prerequisites: 54-302 and 54-301

54-440 Production Prep:TBD 12

Fall and Spring
Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-441 Costume Design for Dance

Fall: 5 units
A mini exploring the design elements specific to the aesthetic and performance requirements of dance. The course will examine the design of costumes at significant points in the history and evolution of dance, from classical ballet to a wide range of modern genres. Coursework will consist of lectures, visual presentations, viewing of filmed footage of notable dance performances, and research and design projects. PRE-REQUISITE: Design/PTM Costume major. All others: Portfolio Review and special permission of teacher required. FOR: Second year Graduate Costume Design majors and Junior Costume Design students.

54-442 Costume Design for the Classics

Spring: 5 units
This course focuses on left and right brain approaches to complex classics written by a playwright chosen from amongst Moliere, Brecht, Pedro Calder and #243;n de la Barca, and Shakespeare, as well as contemporary female playwrights such as Sarah Ruhl, Ellen McLaughlin and Lauren Gunderson who have written plays inspired by the classics. Special attention is paid to process: research, critical thinking, character development, style, nuts and bolts paperwork, and the honing of each individual designer's skills. PRE-REQUISITE: Design/PTM Costume major. All others: Portfolio Review and special permission of teacher required. FOR: First year Graduate Costume Design majors and Junior Costume Design students. Prerequisite: 54-341
Prerequisite: 54-341

54-443 Production Prep: Looking at You

Fall and Spring
Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-444 Advanced Designer Draping

Spring: 6 units
Advanced Designer Draping is a continuation and development of the proficiencies established in Draping for the Designer I. This course emphasizes the draper's role in the creation of period women's wear: its history, unique pattern challenges, specific construction techniques, and how to manage its creation in the workroom. The synthesis of historical understanding with requirements for the performing arts is underscored. Through the patterning, fitting and making of a multi-layer, historic costume each student undertakes interrelated projects that allow for the application of research, development of complex patterns, composition of complete construction plans and fostering of effective teamwork. To take this class, the student needs to have taken either 54-373 Draping for the Designer I or 54-814 Draping for the Graduate Designer I or to have a background in draping and gain permission from the instructor.
Prerequisite: 54-373

54-445 Commercial Intensive

Fall: 3 units
This course helps actors to develop an understanding of commercial type, work with commercial copy, learn about the SAG-AFTRA commercial contract and use wardrobe, technology and self-taping to best effect in order to book commercial work.

54-446 Professional Prep for Costume Designers

Spring: 3 units
An optional professional preparation course geared toward Costume Designers entering the theatre industry. The slide/lecture course will cover doing taxes, job search information: including resume formatting, cover letter styles and tone, portfolios and websites; United Scenic Artists' union membership and benefits, "How to Survive the First Years in the Business." Minimal homework.

54-447 Figure Drawing

Fall: 3 units
Costume Majors have priority, then Design Majors. This course explores the realistic and expressive depiction of the human form primarily in two dimensional media. Working primarily from the live model, exercises will be undertaken that address gesture, proportion, movement, anatomy and structure, composition and expressive form. Students will experience a variety of media and formal approaches to the figure, working from nude, draped, and clothed male and female models. A primary goal of the class is to develop the ability to create the human figure from imagination, based on intensive empirical study of the forms and structures of the human body from life.

54-449 Production Prep: Carnegie Scenic

Fall and Spring
tbd

54-450 Painting for the Theatrical Designer

Intermittent: 9 units
Taught 2 days a week every other Spring, watercolor and acrylics are explored for scene, lighting and costume designers with discipline specific studies such as architecture, furniture, landscapes and interiors as lit for scene and lighting designers; human costume and accessories for costume designers.
Prerequisite: 54-473

54-451 Scenic Design Packet

Fall and Spring: 4 units
In Scenic Design Packet students will explore the full process and craft of scenic design deliverables, working with a previously designed class project. The course is a companion course to Scenic Design Bootcamp, taking one of the preliminary scenic design ideas to a complete final scenic packet. Through demonstrations, laboratories, and project work, students will create portfolio worthy drafting, models, paint elevations, storyboards and properties information.

54-452 Architectural Lighting Design

Spring: 4.5 units
The study of Architectural Lighting Design for interior and exterior spaces.
Prerequisite: 54-252

54-453 Production Management Workshop

Fall and Spring: 3 units
Investigates the organization, planning and interpersonal skills required to successfully manage a live theatrical production. Course is discussion based on 1) participants experience in laboratory productions in the School of Drama, 2) current practical examples of experiences of professional production managers, and 3) contemporary management texts. Topics covered include: Budgeting, Scheduling, Communication, and Project Management. Permission of instructor required.

54-454 Advanced SM: Management Styles

Fall and Spring: 6 units
In-depth exploration of Management Styles, examination of personal approaches, collaboration, and priorities for the future

54-455 Production Data Manipulation

Spring: 9 units
In depth analysis of how to work with production data across multiple software platforms to allow the Production Manager to make more informed decisions. Required for Production Management / Stage Management majors.

54-456 Production Preparation

Fall and Spring
Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. In the Lighting Production course students will work within technical lighting teams to support production work on School of Drama shows and events.

54-457 Directing: Production IV

Fall
SENIOR DIRECTING CAPSTONE: Fully-designed presentation directed by a 4th-Year Directing student with the following goals: to publicly realize a playwright's purpose for an audience; to tell an entire theatrical story with a beginning, progression and amp; ending; to extend practical understanding of Theatre as a collaborative process; to synthesize and amp; apply prior studies at Carnegie Mellon, or other approved Capstone Project.

54-458 Directing: Production IV

Spring
SENIOR DIRECTING PROJECT: This is a 90-minute, public, fully-designed presentation directed by a 4th-Year Directing student with the following goals: to publicly realize a playwright's purpose for a live audience; to tell an entire theatrical story with a beginning, progression and amp; ending; to work as a team with actors and amp; design team to shape a cohesive and amp; coherent theatrical presentation; to extend practical understanding of Theatre as a collaborative process; to synthesize and amp; apply prior studies at Carnegie Mellon.

54-459 Future Stages for Undergrad Directors and Dramaturgs

6 units
FUTURE STAGES is a graduate level course (Drama undergraduates by permission only) which combines options from the School of Drama in a new configuration: through working collaboratively across disciplines, students investigate multimedia approaches to contemporary theater and new ways of storytelling. Directors, designers, actors, and dramaturgs work in groups to generate original ideas, images, texts, and material in a workshop environment. These working groups create projects over the course of the semester which are shown in informal presentations. The emphasis is on process, not product and #8212; devising an interdisciplinary performance requires a keen focus on combining creative invention with a rigorous structure of concept development and #8212; both of which are explored here. We also examine the work of several significant contemporary theater artists whose work approaches collaboration across a variety of disciplines. Artists have included: Ariane Mnouschkine, Dumbtype, Complicite, Ralph Lemon, Robert LePage, and more. Students learn to define and distinguish these artist's approaches through viewing video excerpts, readings, and discussion. This class is an opportunity to explore avenues outside of traditional production modes and beyond each student's individual discipline. We focus on the process of creating a theatrical language which truly integrates disciplines.
Prerequisite: 54-222

54-461 Experimental Capture

Fall and Spring: 12 units
This class will strengthen the student's video content creation process while centering conceptual strength in video design for live applications. Skills taught will focus on workflows and best practices for creating media content for live performance context. Tools and skills taught include FFMPEG transcoding, video generation via Touchdesigner, Advanced Millumin and NDI workflows. This intensive workshop style class's corequisite is the course Expanded Theater. This pairing will allow students to apply the skills acquired in this class to multiple collaborative and live mediated projects. Class time will be reserved for technical lectures/demonstrations.

54-463 Production Prep: Transformations (SOM 1)

Fall and Spring
Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-464 PTM Professional Practice

Spring: 3 units
A seminar about issues surrounding a career as a technical manager. In a series of presentations and discussions students will encounter tools and strategies for job seeking and personal promotion. Guest lecturers will present materials on professional obligations like insurance and taxes and non-salary compensation like retirement and health benefits.

54-465 Production Prep: Gloria

Fall and Spring
Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-466 Advanced Entertainment Lighting Programming Lab

Spring
Students will explore advanced techniques and methods while programming on top-end lighting control systems.

54-467 Costume Design with Music

Spring: 5 units
A second semester exploration of costume design for musicals and opera that engages students in aesthetic and practical techniques applied toward these two genres. Extensive presentations of the history of opera and musicals comprise most of this class. Students choose the opera or musical they wish to design. Special attention paid to music skills, glossary, process, research, designing for principals and chorus, swatching, nuts and bolts paperwork and the honing of each designer's individual skills. PRE-REQUISITE: Design/PTM Costume major. All others: Portfolio Review and special permission of teacher required. FOR: First year Graduate Costume Design majors and Senior Costume Design students.

54-468 Theater Management

Intermittent: 6 units
The course examines theatre enterprises, focusing on both existing and emerging business models for producing or presenting theatre organizations from Broadway to Omaha. Theatres are uniquely responsive to their audiences and ecosystems, hence, the course will investigate how the business works - internally and externally. While programming (plays) are at the core of the theatrical exchange, this course will focus its attention on the institutional frameworks that provide the financing, staffing and audiences to those works. The course will be organized in a seminar structure. Lecture will occur to deliver core concepts but the course emphasizes discussion, individualized investigations and creative projects.

54-469 Dance Lighting Design 1

Fall: 3 units
Through hands-on exploration, lecture and discussion, students will develop a design process for lighting dance. Topics will include: historical background of dance roots, approaches to lighting ballet and modern dance, designing a dance rep plot, and dance lighting techniques.

54-470 Costume Rendering

Spring: 9 units
This fast-paced course focuses on techniques and exercises specific to the development of versatile costume renderings enhanced by the mediums used in the creation. A variety of mediums and methods are explored including colored pencil, marker, ink, Doctor Martin's dyes, watercolor and acrylic as well as transfer drawings, resists and the use of a range of techniques. Color, texture, pattern, nude and clothed human models are carefully studied and rendered. Students also apply course techniques to the development of designs for production and portfolio preparation. PRE-REQUISITES: Drawing for the Theatrical Designer, Major in Design Option of School of Drama FOR: Graduate and Undergraduate Design Costume Majors only. Instructor Approval required. Prerequisite: 54-473
Prerequisite: 54-473

54-473 Drawing for Theatrical Designers

Fall: 9 units
This semester-long basic drawing course focuses on developing hand-eye coordination through discreet studio exercises that allow the theatre student multiple entry points into drawing. Developed for theatrical design students, accurate drawing of proportion while viewing first hand subjects and research images is stressed. Marker and pencil use only. Rigorous practice required. PRE-REQUISITE: Design/PTM major. All others: Portfolio Review and special permission of teacher required. FOR: First semester Graduate Design and Production Students, First semester Junior Costume Majors, other Design/PTM students by consent of instructor.

54-475 Advanced Topics in Stage Management: Cross-Boundaries

Fall and Spring: 6 units
This class will use the theory of cultural intelligence to explore cross-cultural and interdisciplinary collaboration in the world of performing arts and entertainment. We will delve into different interdisciplinary artists and productions' unique culture and process on both national and international platforms. The learning intention is to develop the students' managerial culture awareness and adaptability when encountering different areas including dance, branded experiences, theme park, cruise line, award shows, concerts, and USO Entertainment (United Service Organizations).

54-476 Media Creation Studio

Fall: 6 units
This class will strengthen the student's video content creation process while centering conceptual strength in video design for live applications. Skills taught will focus on workflows and best practices for creating media content for live performance context. Tools and skills taught include FFMPEG transcoding, video generation via Touchdesigner, Advanced Millumin and NDI workflows. This intensive workshop style class's corequisite is the course Expanded Theater. This pairing will allow students to apply the skills acquired in this class to multiple collaborative and live mediated projects. Class time will be reserved for technical lectures/demonstrations. The majority of work associated with project assignments will take place in the corequisite Expanded Theater.

54-477 Technical Direction III

Fall: 6 units
Required for all senior undergraduate Technical Direction students. This "capstone" course is the second semester of a sequence requiring application of concepts from earlier courses including Standard Scenery Construction, Production Planning, Structural Design, Stage Machinery Design and Technical Design 1. This is a project-based course requiring weekly presentation of solutions to various "unusual" technical challenges, drawn from actual production experiences. Thorough documentation (shop drawings, budgets, build schedules, etc.) is a requirement for each project.
Prerequisite: 54-378

54-478 Lighting for the Camera

Fall: 3 units
Through hands-on exploration in a studio setting, students will learn the basics of how to light for camera. A professional television lighting designer will mentor the students through the design process in a three-day workshop. Student teams will be formed comprised of a director, writer, lighting designer, costume designer, art director and actors. Each teams script will be produced in the Wells Video Studio as a three-camera shoot. Following the completion of taping each scene, students will view the final results and receive feedback on their work.
Prerequisite: 54-469

54-479 Lighting for the Camera 2

Intermittent: 3 units
Through hands-on exploration in a studio setting, students will learn the basics of how to light for camera. A professional television lighting designer will mentor the students through the design process in a three-day workshop. Student teams will be formed comprised of a director, writer, lighting designer, costume designer, art director and actors. Each teams script will be produced in the Wells Video Studio as a three-camera shoot. Following the completion of taping each scene, students will view the final results and receive feedback on their work.
Prerequisite: 54-252

54-480 Technical Direction IV

Spring: 6 units
The purpose of this class is to prepare Technical Directors as Technical Designers, specifying the engineering and fabrication of discrete scenic elements in a production context. Upon completion of this course, students should be able to: Understand how elements function to support production Recognize the limitations of standard approaches Develop unique approaches to technical challenges where appropriate Work with an ever-expanding body of methods, materials and hardware Integrate knowledge from prior PTM coursework Develop effective drawings and prototypes Iterate technical designs to achieve optimization
Prerequisite: 54-477

54-486 Understanding Textiles

Spring: 3 units
Understanding Textiles is a half-semester introduction to the textiles used for the performing arts. This course begins with an overview of the historical development of textile technology and the role cloth plays in world economies. Next it examines weaving structures and how they impact suitability for particular applications. Techniques for identifying fibers, weaves and fabric density are learned. The course culminates with a project that uses all the explored skills, a fabric in history swatch book. Each student takes an era of history, researches cloth production at that time, finds period appropriate swatches, accurately identifies them and suggests uses for each. These individual chapters are combined into a large resource book, a copy of which each participant keeps for future reference.

54-487 Dramaturgy: Production II

Fall and Spring: 12 units
Working as a production dramaturg for a School of Drama production in the junior year.

54-488 Dramaturgy: Production II

Spring
Working as a production dramaturg for a season show or a professionally-produced show at a LORT or similarly-ranked theatre in the US or abroad, in senior year.

54-489 Dramaturgy: Internship

Fall and Spring: 9 units
Professional internship with a dramaturg at a LORT or similarly-ranked theatre in the US or abroad.

54-490 Special Topics in Media: Mediated Reality

Spring: 10 units
Mediated Realities is an advanced studio course that investigates the potential applications of mediated-reality technologies and location-based interactivity for storytelling, site-specific art-making, and live performance (broadly defined). Converging trends in cultural production, mobile computation, and media technologies present new affordances for artists and designers to shape location-based experiences. Studio work engages a breadth of strategies in post-media aesthetics, as related to one's experience and understanding of place. Trans-media storytelling, real-time graphics, machine learning, gamification, locative artworks, augmented reality and powerful portable media devices present opportunities for artists and designers to create experiences that heighten multisensory experience by merging live performance and participant interaction with systems for digital information, imagery, and 3D visualization - all ubiquitously available in low-cost and widely distributable formats (e.g. apps, mobile web sites). The course frames technological experimentation in the context of 1970's Land Art, Happenings, Fluxus games, Performance Art, Expanded Cinema, and the unresolved theoretical issues emerging from this rich period in American history - site specificity, competing definitions of "community," the effects of media and representation, audience/performer dynamics, and the nature and limits of the art work. Reading discussions, site visits, and presentations from outside experts (CMU faculty, visiting artists) will expose a range of relevant topics, disciplinary and creative perspectives, and potential avenues for investigation. Specific areas of focus will include Pittsburgh history, local ecological dynamics, labor history and the effects of technology on the landscape and lives of Pittsburgh's population.

54-491 Concert Lighting Design

Fall: 9 units
Students will explore lighting design for concert touring. Emphasis will be on the conceptual development, design process, music analysis, methods of rendering ideas and strategies for implementation of designs. The course will demonstrate methods of working with the tools, vocabulary and technology available to the concert lighting designer.

54-493 Business of Acting & The Practice

Fall: 4 units
This course introduces the (advanced) actor to various aspects of the professional world. Emphasis is placed on the audition and interview process for casting directors, talent agents and personal managers. Each student will present either an individual or small group project chosen from a wide ranging list of topics which include performers unions, various production contracts, New York and regional theater season,s professional publications and web sites. Occasional tests are administered on the subject of current Broadway and Off-Broadway seasons. Registration for this course is limited to Drama majors only.
Prerequisites: 54-301 and 54-302

54-497 Directed Study

Fall and Spring
An opportunity to pursue a predefined project or content outside of the standard curriculum under the guidance and direction of a School of Drama faculty member. By special permission only.

54-498 Expanded Theater

Intermittent: 6 units
Expanded Theater is a hands-on studio course where students work with a wide variety of media, network, and computational technologies in a performance-focused workshop environment. Students work in small teams, experimenting and iterating, with low-stakes showings, to gather feedback and see things "on their feet." Through working collaboratively across disciplines, students investigate innovative approaches to contemporary theater and new ways of storytelling. Contemporary techniques for ensemble creation, devising and media integration will be explored through these exercises, readings, and viewing of other artist's work. The course is open to all students who are excited by "thinking with media" and how the systems and technologies we use every day can be incorporated more deeply into the design, dramaturgy, and experience of contemporary performance. The course will take place off-campus at the Melwood Building, and students will have a variety of different spaces to explore the creation of these hybrid media/performance experiences. The CMU Shuttle will allow students to quickly get to and from campus. Considering theater as an ancient technology of mass participation and social cohesion, this course explores how emerging technologies can expand upon the basic theatrical relationships in new and culturally relevant ways. Collaboration and integration of design, media, and storytelling is critical to this approach. The Melwood Building is the former Pittsburgh Filmmakers building that is being re-imagined as a performance and technology research center, engaging many schools and outside partners who are exploring how new technologies, networked systems, and experimental artistic practices bridge previously separate disciplines and open-up new possibilities for storytelling, performance, and art. This course is a model for this new collaborative initiative between Drama, Art, and other CMU Schools.

54-499 Advanced Digital Image

Intermittent: 6 units
Advanced Digital Image: (Mini) This class is designed to teach students how to conceive, create and present large scale, professional-quality imagery at "realistic" budget levels. Students choose specific theatrical scenes and create a media based solution for them. Through in-class workshops and Media Lab work-time, this class covers High Definition video production, editing, animation and amp; live video systems for the stage as well as a variety of media-server based presentation technologies. For Juniors, Seniors and Grads. No Prerequisite Open to non-majors

54-500 Voice Lab

Fall and Spring: 5 units
FOR MUSIC THEATRE MAJORS ONLY. Singing Voice based on speech-level and classical singing techniques, required of all Musical Theatre Majors Lessons are private, for the duration of one hour per week. Voice Lab combines all students of Musical Theatre in a one-hour performance class, where repertoire is performed for faculty and students alike. Training is progressive, with each semester building on the vocal mastery achieved from the previous semester. Repertoire spans from classical to rock, but with an emphasis on songs extracted from the American Musical Canon.

54-503 Directors' Practicum

All Semesters: 2 units
A mini-semester course introducing career paths and professional tools for directors.

54-505 Ear Training

Fall: 1 unit
Ear Training for sound designers and audio technologists. Introduction and development of skills and techniques for discerning, measuring and expressing the physical qualities of sound with accuracy and sensitivity. Topics include recognizing frequencies (1/3 octave and dual-octave) and analyzing effects and processing (pitch, amplitude, time domain and timbral). This course is open to Drama Sound Design majors/minors, Music Technology major/minors or by permission of the instructor.

54-508 Theatrical Sound System Design 1

Fall: 9 units
Intensive course exploring the theory, art and technology of large scale sound system design for entertainment, specifically live theater productions.

54-509 Theatrical Sound System Design 2

Fall: 9 units
Intensive course exploring the theory, art and technology of large scale sound system design for entertainment, specifically live theater productions. Prerequisites: Intro to Sound Design for Theatre and Production Audio, OR permission of instructor.
Prerequisites: 54-666 and 54-166

54-511 Millinery I

Fall: 9 units
This course surveys basic hat making skills and allows students to create project work in the areas of simple construction, blocked felt and buckram shapes.

54-513 Millinery II

Spring: 9 units
Millinery II (513/914):This course continues the explorations begun in Millinery I. The student undergoes advanced exercises in straw, wire frames, block making and non-traditional millinery materials. Continued emphasis is given to developing professional level skills and assimilation of advanced theories.
Prerequisite: 54-511

54-516 Fabric Painting

Spring: 9 units
This course is structured as a lecture/demonstration and lab employing the principles of fabric painting/printing techniques, fabric painting/printing materials and the practical use of these techniques and materials. The student should learn the basic concepts behind each of the covered processes, the materials and alternate methods involved with each process, and introductory concepts behind pattern registration. Additionally, the world of breakdown and distressing is covered in an ongoing exercise that spans the duration of the semester.

54-517 Directors Common Hour

Fall: 1 unit
Directors Colloquium is a weekly meeting for undergraduate Directing majors and BXA students in directing. Specific topics in directing are discussed and School of Drama productions are critiqued.

54-518 Director's Colloquium

Spring: 1 unit
Missing Course Description - please contact the teaching department.

54-519 Acting for the Camera

Fall: 6 units
This course teaches the skills necessary to work as an actor in the film and television industry. Incorporating the proficiencies and techniques acquired during previous training, we'll learn and practice the additional skills required to work on camera.
Prerequisite: 54-302

54-520 Acting for the Camera

Fall and Spring: 8 units
This course teaches the skills necessary to work as an actor in the film and television industry. Incorporating the proficiencies and techniques acquired during previous training, we'll learn and practice the additional skills required to work on camera.
Prerequisite: 54-302

54-521 Video Media Design Senior Thesis

Spring
TBA

54-522 Director/Dramaturg Play Lab

Spring: 3 units
Run by and for the directors and dramaturgs of the sophomore class, this course will foster collaboration while reading new plays every week. With a focus on analysis, presentation, and pre-production skills, the goal is to bring together directors and dramaturgs, while preparing for BFA Directors' Senior Capstone project

54-524 Dance Lighting Design 2

Fall: 3 units
Through discussions and collaboration students will develop a design process for lighting dance. The students will participate in the creation of a shared lighting plot for the next season's Dance/Light Concert.
Prerequisite: 54-469

54-525 Entertainment Lighting Programming

Fall: 9 units
Students learn and practice programming techniques on the MA2 series of lighting control consoles. Advanced programming techniques are explored, including media server control and user-defined commands for the console. Different applications are introduced, but the primary focus is on programming for live music performance.
Prerequisites: 54-349 or 54-337

54-527 Automated Lighting Workshop

Spring
In the spring semester Automated Lighting Workshop course will consist of seven distinct modules. The first will focus on the operation and maintenance of equipment that falls into the category of automated lighting. The second module will focus on the programming of media servers using lighting consoles. This year Eos Family consoles and MBox will be used. The third module will concentrate on the development of previsualization skills using LightConverse software. In the fourth portion of the class students will engineer the automated lighting rig that will be used for the summer and fall of 2020 in the Wells Video Studio. The fifth module will be a continuation of programming on the Hog4 console, concentrating on preparing students for the national Hog Factor competition. Module six will be an introduction to the Vx76 line of control consoles. In the seventh module students who have experience on the GrandMA2 line of consoles may continue the development of skills on that platform.
Prerequisite: 54-349

54-534 Costume Crafts: Theatrical Footwear

Spring: 5 units
This introductory course serves to instruct the student in the language, materials and processes of designing, creating and adapting footwear for the stage.

54-535 Costume Crafts: Fabric Modification

Spring: 5 units
This course is intended to introduce the student to processes of fabric modification that utilize techniques beyond painting and dyeing. Students will be encouraged to investigate the world of garment decoration and to actively explore a wide variety of processes and materials ranging from old world needle arts to modern crafts which utilize long established techniques in contemporary context.

54-536 Costume Crafts: Mask Making

Spring: 6 units
This course opens the world of mask creation to the adventurous student. A broad range of techniques are touched upon and explored allowing students to pick and choose those processes which appeal to their aesthetic and apply to their needs.

54-539 Fabric Dyeing I

Fall: 9 units
This course is designed to provide the student with an introductory level of instruction for a broad range of fabric dyeing and painting techniques. -Students should gain an understanding of the various dye classes and their safe use in dyeing fabric for the theatre. -The student should gain a full comprehension of the processes of each of these classes, including common terminology, and be able to correctly enumerate steps in the processes. -The student should be able to match the appropriate product to the demands of the project. -The student should gain skills necessary to manipulate the dye process to achieve desired results including exercising their understanding of color theory. -The student should gain a basic understanding of several specialty dye techniques that could excite further exploration.

54-548 Sound Forum

Spring: 1 unit
Twice weekly meeting of all declared sound design majors to discuss production assignments and issues surrounding productions.

54-561 The Films of the Coen Brothers

Fall and Spring: 6 units
Films of the Coen Brothers

54-565 Dance/Light

Fall: 3 units
A practical application of the knowledge and skills learned in Dance Lighting Design 1+2. The class shares the experience of each student creating the lighting for at least one dance performance piece in the Dance/Light Concert.
Prerequisite: 54-524

54-585 Dramaturgy Capstone Thesis

Fall: 9 units
No course description provided.

54-587 Dramaturgy Production

Fall and Spring: 12 units
This course provides dramaturgy students with the opportunity to engage in production dramaturgy on a School of Drama production. Expectations and tasks for these courses will be determined in consultation with the advisor on the production, and may include, but are not limited to: script preparation and analysis, rehearsal dramaturgy, gathering and curating of materials for the director, designers, and actors, lobby display curation and creation, the writing of a program note, audience outreach, facilitation of talkbacks and pre-show discussions, and other dramaturgical tasks/activities as needed for a particular production.

54-588 Dramaturgy Production III

Spring
For Dramaturgy majors.

54-590 The Post Apocalypse on Film

Spring: 6 units
This course will survey cinematic treatments of the end of civilization from a wide variety of filmmakers. We will analyze the cultural, philosophical, mythical and political elements of each film. We will also discuss the technical and artistic aspects in order to better understand the genre and filmmaking in general. The goal is for each student to develop ways to think critically about film.

54-592 Costume Crafts: Theatrical Armor

Fall: 5 units
This mini course introduces the student to the world of armor creation for the stage. Techniques covered range from traditional to revolutionary and provide the student with a breadth of possibilities geared toward solving the general conundrum of successful armor for the theatrical production.
Prerequisite: 54-538

54-593 Stanley Kubrick and His Films

Intermittent: 6 units
Stanley Kubrick and His Films Stanley Kubrick and His Films will explore the amazing diversity in this excellent film director's output from 1967-1999. The course will emphasize the psychological and moral issues raised in his films. And the course will focus on his camera techniques, his use of sound and music, and other remarkable innovative elements. With each film, Kubrick seems to re-invent himself, expanding the dimensions of film art. Films that will be shown in class include: "Paths of Glory" (1957), "Lolita" (1962), "Dr. Strangelove" (1964), "2001: A Space Odyssey" (1968), "A Clockwork Orange" (1971), "Barry Lyndon" (1976), "The Shining" (1980), "Full Metal Jacket" (1987) and "Eyes Wide Shut" (1999).

54-599 Woody Allen and Mel Brooks films

Fall: 6 units
TBA

54-617 Independent Study in Dance

Fall and Spring
Independent Study in Dance with faculty approval.

54-633 The Basics of Self-Producing for Theater Artists

Spring: 6 units
Is self-producing for you, or do you prefer to use other people's resources? Basics of Producing for Theater Artists will introduce the mechanics of getting your work to the spectator while creating a sustainable life as an artist. We'll investigate old models and new platforms to help you find the location and the recipe for your unique mission. We will walk through budgeting, fundraising, marketing, contracts, rights, risks, and the audience of the future. As a final project, you will assemble a package you can hand to a potential funder that explains why your theater is needed to fill a void in the culture, and why no one is better suited to do it.

54-648 And One More Thing

Fall: 3 units
Technical Direction alumni make guest appearances to discuss topics they wish had been covered as part of the program (or even to make the occasional correction).
Prerequisite: 54-777

54-666 Production Audio

Spring
Introduction to the theories and technologies used in sound system design for theater and live entertainment. Sound Majors: Register for Section A, 6 Units Non-Majors: Register for Section B, 4 Units

54-672 Production Prep: TBA 2

Fall and Spring
Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-711 The Dye Room in Practice: Exploration in Practical Dyeing for Theatrical Artisan

Spring: 3 units
An Exploration in Practical Dyeing for the Theatrical Artisan

54-714 Costume Rendering

Spring: 9 units
This fast-paced course focuses on techniques and exercises specific to the development of versatile costume renderings enhanced by the mediums used in the creation. A variety of mediums and methods are explored including colored pencil, marker, ink, Doctor Martin's dyes, watercolor and acrylic as well as transfer drawings, resists and the use of a range of techniques. Color, texture, pattern, nude and clothed human models are carefully studied and rendered. Students also apply course techniques to the development of designs for production and portfolio preparation. PRE-REQUISITES: Drawing for the Theatrical Designer, Major in Design Option of School of Drama FOR: Graduate and Undergraduate Design Costume Majors only. Instructor Approval required. Prerequisite: 54-811
Prerequisite: 54-811

54-721 Graduate Directing: Text to Stage

Spring: 9 units
TBD

54-722 Graduate Directing: Text to Stage

Fall: 9 units
Text to Stage is a studio laboratory course for graduate CMU MFA directing students.

54-729 Automated Lighting Workshop

Fall and Spring
In the spring semester of the 2019/2020 academic year the Automated Lighting Workshop course will consist of seven distinct modules. The first will focus on the operation and maintenance of equipment that falls into the category of automated lighting. The second module will focus on the programming of media servers using lighting consoles. This year Eos Family consoles and MBox will be used. The third module will concentrate on the development of previsualization skills using LightConverse software. In the fourth portion of the class students will engineer the automated lighting rig that will be used for the summer and fall of 2020 in the Wells Video Studio. The fifth module will be a continuation of programming on the Hog4 console, concentrating on preparing students for the national Hog Factor competition. Module six will be an introduction to the Vx76 line of control consoles. In the seventh module students who have experience on the GrandMA2 line of consoles may continue the development of skills on that platform.
Prerequisite: 54-771

54-755 Drama Practicum

Summer: 3 units
This course provides 3 units of pass/fail credit for students participating in a drama related internship. The student must be registered for this course during the internship, in order to earn the credit. At the end of the term, the student's supervisor must email the academic advisor with a brief statement describing the student's activities, and an evaluation of the student's performance. Students are required to submit a statement, reflecting on insights gained from the internship experience. Upon receipt of both statements, the academic advisor will assign a grade of either P or N, depending on the outcome.

54-756 Theatre for the Ear

Spring: 6 units
Survey of aural storytelling with technology focusing on forms with no visual component. Topics include the history of radio drama to present day, radio sound art, cut-up and tape manipulation, comedy records and podcast dramas. Prerequisites: 54-767 Graduate Conceptual Sound Design 1 and amp; 54-768 Graduate Conceptual Sound Design 2 OR 54-791 Playwriting I. Restrictions: The course is open to Graduate Sound Design majors, Graduate Dramatic Writers or with permission of the instructor.

54-759 Working with Dramaturgs

Intermittent: 3 units
This mini-2 course enrolls writers with fully drafted dramatic works in progress and pairs them with student dramaturgs to advance the development of those works according to the writers' goals. Students develop collaborative skills and understanding of the role a dramaturg can play in new play development. Required of Dramatic Writing graduate students; open to other writers with instructor permission.

54-760 Grad Leadership Workshop: Ethics & Innovation

Intermittent: 6 units
This course will be an exploration of both innovative strategies and the ethics of leadership within the performing arts. It will build on the management principles covered in foundational courses and is designed to offer the student an approach to leadership development that is tailored to the individuals strengths and needs as well as their role within theatrical organizations. For PTM students only or with permission from the instructor.
Prerequisite: 54-749

54-766 Introduction to Sound Design for Theatre

Spring: 6 units
Students explore the basic principles and theories of sound design from technical, psychological and aesthetic standpoints. Course work includes instruction in the controllable properties of sound, practical planning of sound plots, cue creation, and the design process. Restrictions: Open to all Graduate Drama Majors, CFA graduate students or with permission of instructor.

54-773 Couture Sewing Techniques

Intermittent: 9 units
This course is designed to help the student gain an understanding of and appreciation for high-end sewing and finishing techniques and how these techniques improve the quality of the clothing they are employed in. -The student should gain a comprehension of the terminology commonly used in couture sewing and high-end finishing. -The student should gain a full comprehension of the process of each of these techniques and be able to logically enumerate steps in the full process involved with each technique. -The student should be able to appropriately apply each technique and distinguish between techniques when making choices in the sewing process.

54-780 Fabric Painting

Spring: 9 units
This course is structured as a lecture/demonstration and lab employing the principles of fabric painting/printing techniques, fabric painting/printing materials and the practical use of these techniques and materials. The student should learn the basic concepts behind each of the covered processes, the materials and alternate methods involved with each process, and introductory concepts behind pattern registration. Additionally, the world of breakdown and distressing is covered in an ongoing exercise that spans the duration of the semester.
Prerequisite: 54-845

54-795 Costume Crafts: Mold Making and Casting

Spring: 6 units
This course is designed to introduce the student to a wide variety of molding and casting techniques that might be encountered in the costume crafts area. Upon completion of this course students should understand basic products and processes available to them to enhance either their design work or their production capabilities. By no means is this an exhaustive survey and further study is encouraged.

54-796 The Basics of Self-Producing: How to Put Up Your Show in NYC and Get It Reviewed

Intermittent: 6 units
For any actor/writer/director/theatre artist in New York City, the time between jobs can feel stressful and frustrating. Self-producing is the quickest way to get your work on stage without permission from anyone else or having to adhere to anyone else's restrictions. From blurbs to budgets to rehearsal space to press releases to equity paperwork, this course covers everything you need to know in order to get your work produced and noticed in New York City without breaking the bank. This course will draw from readings on independent theatre, interviews with working independent producers in New York, and the working experience of Anderson Cook, author/producer of The Disembodied Hand That Fisted Everyone to Death - the Musical!, Blatantly Blaine, Pop Punk High, Donny and Kelly Save the Slumber Valley ASPCA, and more - all produced and reviewed in NYC.

54-815 Graduate Negotiation and Conflict Management

Fall: 3 units
This class is a focused exploration of the process of negotiating, both formally and everyday. We will examine interactions on all levels and environments, with an evaluation of tactics, strategies and the measure of success. From there, the class expands into the nature of conflicts and the manager's role in identifying and confronting them. Throughout the class, we hope to find solutions to implement in our lives and work. In-class exercises and role play will be a fundamental part of class activity.

54-819 Figure Drawing

Fall and Spring: 3 units
Costume Majors have priority, then Design Majors. This course explores the realistic and expressive depiction of the human form primarily in two dimensional media. Working primarily from the live model, exercises will be undertaken that address gesture, proportion, movement, anatomy and structure, composition and expressive form. Students will experience a variety of media and formal approaches to the figure, working from nude, draped, and clothed male and female models. A primary goal of the class is to develop the ability to create the human figure from imagination, based on intensive empirical study of the forms and structures of the human body from life.

54-832 Design for Spaces

Spring: 4.5 units
This course focuses on creating design for performance, and for this Mini will focus specifically on designing new work for the stage. Playwrights and designers will work collaboratively towards a shared understanding of each discipline's storytelling and world-building process. This is an opportunity for each writer to workshop the world of their script with designers just as they might workshop the text of the play in a reading with actors. Just as different actors and directors might interpret a text differently, so too will different designers; in this class, each play script will have multiple worlds created by randomly assigned design students. Designer-writer collaboration will encourage exploration of adaptive design and focus on developing design tools in areas such as: research, design conception, rendering model making, and storyboards. Playwrights will likewise explore responsive, collaborative approaches in their script revisions. The shared goal for both playwrights and designers is to conceive a world on stage in four dimensions: length, width, height, and most importantly time.

54-880 Special Topics in Media: Mediated Reality

Spring: 10 units
Mediated Realities is an advanced studio course that investigates the potential applications of mediated-reality technologies and location-based interactivity for storytelling, site-specific art-making, and live performance (broadly defined). Converging trends in cultural production, mobile computation, and media technologies present new affordances for artists and designers to shape location-based experiences. Studio work engages a breadth of strategies in post-media aesthetics, as related to one's experience and understanding of place. Trans-media storytelling, real-time graphics, machine learning, gamification, locative artworks, augmented reality and powerful portable media devices present opportunities for artists and designers to create experiences that heighten multisensory experience by merging live performance and participant interaction with systems for digital information, imagery, and 3D visualization - all ubiquitously available in low-cost and widely distributable formats (e.g. apps, mobile web sites). The course frames technological experimentation in the context of 1970's Land Art, Happenings, Fluxus games, Performance Art, Expanded Cinema, and the unresolved theoretical issues emerging from this rich period in American history - site specificity, competing definitions of "community," the effects of media and representation, audience/performer dynamics, and the nature and limits of the art work. Reading discussions, site visits, and presentations from outside experts (CMU faculty, visiting artists) will expose a range of relevant topics, disciplinary and creative perspectives, and potential avenues for investigation. Specific areas of focus will include Pittsburgh history, local ecological dynamics, labor history and the effects of technology on the landscape and lives of Pittsburgh's population.

54-884 Graduate Digital Narratives

Fall: 5 units
This course combines options from the School of Drama in a unique configuration: through working collaboratively across disciplines, students will investigate innovative approaches to contemporary theater and new ways of storytelling. Contemporary techniques for ensemble creation, devising and media integration will be explored through exercises, readings, and viewing of other artist's work. This Fall the course will explore the wide variety of digitally mediated forms for online, remote and distanced work - techniques of collaboration, creation and experiencing of performance focused work. We will pursue multiple techniques for cross-platform storytelling, drawing from students' lived experiences to engage the current political and social milieu via multiple digital and mediated systems. Experimental and devised processes of theater making have long mined the complex relationship between the form and the content of an artwork - how can we do so in pursuit of a critical/political perspective? Students will become familiar with contemporary and historical companies who work this way and through small group in-class workshops create new narrative experiences and share them with the larger class. Through embracing these tools and forms, we utilize the theatrical conversation to engage in artistic discourse to discover new complexities of meaning. We invite students to come explore these possibilities in a spirit of experimentation and group exploration.

54-905 Ear Training

Spring: 1 unit
Ear Training for sound designers and audio technologists. Introduction and development of skills and techniques for discerning, measuring and expressing the physical qualities of sound with accuracy and sensitivity. Topics include recognizing frequencies (1/3 octave and dual-octave) and analyzing effects and processing (pitch, amplitude, time domain and timbral). This course is open to Drama Sound Design majors/minors, Music Technology major/minors or by permission of the instructor.

54-929 Writing for Television

Spring: 9 units
TBD

54-939 Entertainment Lighting Programming

Fall: 9 units
Students learn and practice programming techniques on the MA2 series of lighting control consoles. Advanced programming techniques are explored, including media server control and user-defined commands for the console. Different applications are introduced, but the primary focus is on programming for live music performance.
Prerequisites: 54-771 or 54-837

54-964 Graduate Scenic Design: Moving the Musical

Fall: 5 units
Designing scenery for a musical presents a number of specific and unique issues, often quite different than designing straight play. Addressing not only the story and the meaning of the piece is of course important but one must pay close attention to the style of the music and the way the songs are incorporated into the text. How do these elements help to tell the story? This course will allow you to explore how scenery moves and the ways in which it can enhance a text.

54-972 PTM Professional Practice

Fall: 3 units
A seminar about issues surrounding a career as a technical manager. In a series of presentations and discussions students will encounter tools and strategies for job seeking and personal promotion. Guest lecturers will present materials on professional obligations like insurance and taxes and non-salary compensation like retirement and health benefits.

54-973 Costume Production Thesis

Fall and Spring: 12 units
TBD

54-997 Sound Design For Interactive Environments

Spring: 9 units
This course will examine the process, execution and implementation of sound design for interactive and non-linear storytelling paradigms. Emerging trends in immersive theater, gaming, installation art and multi-media place unique demands on the sound designer both in terms of content and delivery. The student will explore how these demands effect the fundamental processes of design, development of content and flexible delivery systems. Through a combination of directed readings, exploration of current and amp; emerging trends, and project assignments the student will be encouraged to experiment and explore design modes and methodologies that support this flexible method of storytelling.
Prerequisites: 54-868 or 54-867

54-998 Special Topics in Sound Design

Intermittent: 9 units
A one semester course covering various rotating topics including the history and critical theories of film sound design, the history of sound recording and technology, Foley sound, recording and editing techniques, and 5.1 audio. Prerequisites: 54-867 Conceptual Sound Design. Restrictions: The course is open to Drama sound design majors and minors, Music Technology majors and minors or by permission of the instructor.
Prerequisite: 54-867

School of Music

Ross Garin, Acting Executive Director
Location: Hall of Arts 102
www.cmu.edu/cfa/music (http://www.cmu.edu/cfa/music/)

The School of Music at Carnegie Mellon University offers the best aspects of conservatory training within a great university, combining preparation for a lifetime in performance, composition, electronic music, or music and technology with the advantages of learning in an intense academic environment. Every student in the School of Music is a performance, composition, electronic music, or music and technology major. The School of Music is an accredited institutional member of the National Association of Schools of Music.

Each performance major is challenged to develop through individual instruction with a master teacher. The School's relationship with the renowned Pittsburgh Symphony Orchestra is among the strongest conservatory–symphony orchestra relationships in the United States, and Pittsburgh's uniquely strong sense of musical community fosters close relationships with the Pittsburgh Opera, Pittsburgh Chamber Music Society, and a host of other professional musical organizations.

Regular performing ensembles include the Carnegie Mellon Philharmonic, Wind Ensemble, Bagpipe and Drum Band, Baroque Ensemble, Contemporary Ensemble, Exploded Ensemble, Jazz Orchestra, Jazz Vocal Ensemble, Chorus, and Opera. Some of the School's ensembles are instrument specific: Chamber Music ensembles and the Percussion Ensemble, among others. Opportunities for performance are stressed – undergraduate performance majors perform junior and senior recitals, chamber music is publicly presented, frequent performance opportunities on and off campus are provided, and community outreach is vigorously supported.

The School of Music has an intense commitment to new music, led by composition faculty, conductors who devote fully rehearsed cycles of the Philharmonic to works by student composers, and studio faculty whose own performing careers regularly feature new works, and including performances of student works on Contemporary Ensemble programs, and opportunities with the Wind Ensemble and Chorus and on student recitals. The School's state-of-the-art recording facilities are an especially important resource for composers beginning their public careers.

All teaching is entrusted to professional faculty — there are no assistant studio teachers or doctoral teaching fellows — and specialists in Musicology, Theory, Analysis, Counterpoint, Composition, Computer Music, Electronic Music, Eurhythmics, Solfege, Music Education, Pedagogy, Collaborative Piano and Coaching, Acting and Movement, Diction, Literature and Repertoire, Baroque Music, Chamber Music, Conducting, and Sound Recording and Production provide a broad and rich platform for comprehensive musical preparation. At the same time, the university provides the greatest possible support for students combining their majors with minors in all disciplines, unique joint degree programs, and double major programs. These opportunities significantly increase a student's career options and marketability in the changing professional world of music.

School of music Facilities

The teaching facilities of the School of Music are located on the ground, main, and mezzanine floors of the College of Fine Arts, on the ground, main, and second floors of the Hall of Arts, on the first floor of Margaret Morrison Hall, and in WQED Studio A and B. Teaching, rehearsal, and practice rooms are equipped with Steinway pianos. Music students also have access to a state-of-the-art recording studio and music technology cluster. Performances take place in Alumni Concert Hall, Kresge Recital Hall, Carnegie Music Hall, and other venues. The Hunt Library houses a fine collection of books, records, and scores. Listening and conference rooms are also available in the library.

School of Music Options

The School of Music offers a Bachelor of Fine Arts in the following areas:

- Performance (Instrumental, Organ, Piano, Voice)
- Composition
- Electronic Music

The School of Music jointly with the School of Computer Science and the Carnegie Institute of Technology offers a Bachelor of Science in the following area:

- Music and Technology

To earn a Bachelor's degree in any of these options, a candidate must satisfactorily fulfill all the requirements of the School of Music.

Within the options listed above eligible students may apply for specializations in the following areas:

- Dalcroze Eurhythmics Certificate
- Piano Pedagogy Certificate
- Collaborative Piano Minor
- Conducting Minor
- Music Education Minor
- Music Technology Minor
- Music Theory Minor
- Sonic Arts Minor

Dalcroze Eurhythmics Certificate

This program is designed to prepare teachers in the Dalcroze approach to music learning. The course of study includes eurhythmics, piano improvisation, and Dalcroze pedagogy. Carnegie Mellon undergraduates may enter the Dalcroze Training Program during their junior year. However, the certificate will be granted only upon completion of their undergraduate degree. This program is recommended particularly to students who would like to incorporate Dalcroze principles into their teaching and to those who want to obtain more experience in this field.

Piano Pedagogy Certificate

A two-year program leads to certification in piano pedagogy. Students learn to teach piano in a closely supervised environment of class piano instruction. This program has received national acclaim as a model of excellence, with Carnegie Mellon children consistently capturing prestigious awards in national piano competitions.

Collaborative Piano Minor

The collaborative piano minor consists of a six-semester sequence of courses designed to give the student experience with instrumentalists and vocalists. There are individual coaching sessions as well as practical experience in instrumental and vocal studios.

Conducting Minor

This minor is designed for students who are interested in acquiring conducting skills, in anticipation of either graduate study in conducting or a music education career. It includes required courses in conducting techniques for both choral and instrumental ensembles, orchestration, score reading/keyboard harmony, and elective courses in instrumental and vocal methods, diction, and literature and repertoire.

Music Education Minor

This minor is designed for students who are interested in music education, who may wish to complete the requirements for music education certification. Students who complete the requirements for music education certification and pass the Praxis tests will receive Pennsylvania state certification in music (K-12), which is recognized in almost all other states.

Music Technology Minor

The student will take a series of courses which may include electronic and computer music, recording technology, the physics of musical sound, and computer programming. A rich computer music research environment enables talented students to work as programmers with outstanding faculty researchers, whose current projects are gaining international recognition in the areas of computer music and artificial intelligence.

Music Theory Minor

This minor is designed for students who are interested in advanced theory and analysis skills, in anticipation of either graduate study in theory or graduate study that requires a substantial level of theory knowledge. The student will take advanced theory and analysis courses and also support courses in the physics of musical sound and the psychology of music.

Sonic Arts Minor

Students in this minor will explore the processes and products of digital sound and music. They will receive basic training in key component areas: principles of computer music, hybrid instrument building, concepts in sound design. Combining this training with courses that bring together experts from many disciplines, they will create experimental music or explore new, technology-enabled, applications and markets for sound design, music creation, and performance.

Performances and Activities of the School of Music

The School of Music sponsors performances, master classes, and lectures by outstanding national and international guest artists. Announcements of faculty, student, and guest performances are published for the students and the community.

General Requirements for BFA Candidates

Candidates for the Bachelor of Fine Arts degree in composition are required to complete a composition for orchestra in their senior year.

Candidates for the Bachelor of Fine Arts degree in electronic music are required to complete an ambitious capstone project in their senior year that may take the form of an evening length concert, a multimedia experience, an interactive exhibition or app, or some other project that exhibits the student's research and creative output.

Candidates for the Bachelor of Fine Arts degree in performance are required to give public performances in their junior and senior years. Candidates for the Bachelor of Fine Arts degree in string performance are required to give public performances in their sophomore, junior, and senior years.

Candidates for the Bachelor of Fine Arts degree have opportunities to develop teaching skills, particularly as related to their major area of study, in the classes below.

- Instrumental majors: 57-023 Bassoon Studio Performance Class, 57-448 Brass Pedagogy, 57-022 Clarinet Studio Performance Class, 57-018 Double Bass Studio Performance Class, 57-020 Flute Studio Performance Class, 57-021 Oboe Studio Performance Class, 57-030 Percussion Studio Performance Class, 57-016 Viola Studio Performance Class, 57-015 Violin Studio Performance Class, 57-437 Literature and Repertoire.
- Bagpipe, organ and saxophone majors: 57-522 Major Studio (Bagpipe), 57-502 Major Studio (Organ) and 57-514 Major Studio (Saxophone).
- Piano majors: 57-273 Piano Pedagogy I and 57-274 Piano Pedagogy II.
- Voice majors: 57-010 Voice Studio Performance Class.
- Composition majors: 57-627 Independent Study in Supervised Teaching

Candidates for the Bachelor of Fine Arts degree in applied areas other than piano are required to pass a piano proficiency test.

Candidates for Bachelor of Fine Arts degrees in composition and performance are required to pass a major choral ensemble or a major instrumental ensemble as assigned and to pass Convocation every semester of residence in the School of Music.

Candidates for the Bachelor of Fine Arts degree in electronic music are required to to pass Exploded Ensemble or Contemporary Ensemble as assigned every semester of residence and to pass Convocation four semesters of residence in the School of Music.

BFA Curriculum

The music curriculum is based on the following five building blocks:

1. Studio
2. Theory
3. History
4. Ensemble
5. Academics

1. Studio — This is the heart of the school. Students receive individualized instruction with senior faculty in their major area of study: performance or composition or electronic music.

2. Theory — These courses are designed to help students develop listening skills, to acquire theoretical knowledge, to recognize structural techniques and manipulate technological resources. It includes courses in sight-reading, ear-training, eurhythmics, harmony, contrapuntal techniques, analysis of musical forms, 20th-21st century techniques, orchestration, score reading, and electronic and computer music. One music support course in the piano, organ, and instrumental curricula must be a theory course.

3. History - These courses cover in depth the music of the western world and survey the styles and musical structures of non-western music.

4. Ensemble — This area includes student participation in some of the following ensembles: Carnegie Mellon Philharmonic, Wind Ensemble, Bagpipe and Drum Band, Baroque Ensemble, Contemporary Ensemble, Exploded Ensemble, Jazz Orchestra, Jazz Vocal Ensemble, Chorus, Opera, Chamber Music ensembles, and Percussion Ensemble.

5. Academics — The School of Music requires general studies courses (academic courses outside of the School) and elective courses for graduation. These accumulated credits may be applied to minors or majors in other disciplines. Exceptional students in good academic and musical standing within the School are permitted to take additional courses beyond the number required for graduation. There is no charge for extra credits taken at Carnegie Mellon.

Minimum units required for B.F.A. in Music	
Voice majors	**432**
Electronic Music majors	**406**
Composition majors	**386**
Instrumental, Organ, and Piano majors	**386**

Piano

First Year

Fall		Units
57-100	Convocation	1
57-501	Major Studio (Piano)	9
57-4xx	Major Ensemble	6
57-196	Collaborative Piano Skills I	3
57-152	Harmony I	9
57-161	Eurhythmics I	3
57-181	Solfege I	3
57-189	Introduction to Repertoire and Listening for Musicians	3
57-101	Introduction to Music Technology	6
99-101	Core@CMU	3
76-101	Interpretation and Argument	9
		55

Spring		
57-100	Convocation	1
57-501	Major Studio (Piano)	9
57-4xx	Major Ensemble	6
57-197	Collaborative Piano Skills II	3
57-153	Harmony II	9
57-162	Eurhythmics II	3
57-182	Solfege II	3
57-190	Repertoire and Listening for Musicians I	3
57-283	Music History I	9
xx-xxx	Global, Cultural, and Diverse Perspectives Course	9
		55

Second Year

Fall		Units
57-100	Convocation	1
57-501	Major Studio (Piano)	9
57-4xx	Major Ensemble	6
57-672	Chamber Music: Woodwind and Mixed	3
57-151	Counterpoint in Theory and Application	6
57-163	Eurhythmics III	3
57-183	Solfege III	3
57-289	Repertoire and Listening for Musicians II	3

57-284	Music History II	9
xx-xxx	General Studies Course	6
		49

Spring		
57-100	Convocation	1
57-501	Major Studio (Piano)	9
57-4xx	Major Ensemble	6
57-672	Chamber Music: Woodwind and Mixed	3
57-408	Form and Analysis	6
57-164	Eurhythmics IV	3
57-184	Solfege IV	3
57-290	Repertoire and Listening for Musicians III	3
57-285	Music History III	9
xx-xxx	Elective Course	6
		49

Third Year

Fall		Units
57-100	Convocation	1
57-501	Major Studio (Piano)	9
57-4xx	Major Ensemble	6
57-672	Chamber Music: Woodwind and Mixed	3
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective Course	6
		46

Spring		
57-100	Convocation	1
57-501	Major Studio (Piano)	9
57-4xx	Major Ensemble	6
57-672	Chamber Music: Woodwind and Mixed	3
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective Course	6
		46

Fourth Year

Fall		Units
57-100	Convocation	1
57-501	Major Studio (Piano)	9
57-xxx	Performance Elective	9
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective Course	3
		43

Spring		
57-100	Convocation	1
57-501	Major Studio (Piano)	9
57-xxx	Performance Elective	9
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective Course	3
		43

Organ

First Year

Fall		Units
57-100	Convocation	1
57-502	Major Studio (Organ)	9
57-4xx	Major Ensemble	6
57-191	Keyboard Studies	3
57-152	Harmony I	9
57-161	Eurhythmics I	3
57-181	Solfege I	3
57-189	Introduction to Repertoire and Listening for Musicians	3
57-101	Introduction to Music Technology	6
99-101	Core@CMU	3
76-101	Interpretation and Argument	9
		55

Spring		
57-100	Convocation	1
57-502	Major Studio (Organ)	9
57-4xx	Major Ensemble	6
57-191	Keyboard Studies	3
57-153	Harmony II	9
57-162	Eurhythmics II	3
57-182	Solfege II	3
57-190	Repertoire and Listening for Musicians I	3
57-283	Music History I	9
xx-xxx	Global, Cultural, and Diverse Perspectives Course	9
		55

Second Year

Fall		Units
57-100	Convocation	1
57-502	Major Studio (Organ)	9
57-4xx	Major Ensemble	6
57-191	Keyboard Studies	3
57-151	Counterpoint in Theory and Application	6
57-163	Eurhythmics III	3
57-183	Solfege III	3
57-289	Repertoire and Listening for Musicians II	3
57-284	Music History II	9
xx-xxx	General Studies Course	6
		49

Spring		
57-100	Convocation	1
57-502	Major Studio (Organ)	9
57-4xx	Major Ensemble	6
57-191	Keyboard Studies	3
57-408	Form and Analysis	6
57-164	Eurhythmics IV	3
57-184	Solfege IV	3
57-290	Repertoire and Listening for Musicians III	3
57-285	Music History III	9
xx-xxx	Elective Course	6
		49

Third Year

Fall		Units
57-100	Convocation	1
57-502	Major Studio (Organ)	9
57-4xx	Major Ensemble	6
57-459	Score Reading for Composition Majors and Conducting Minors	6
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective Course	3
		46

Spring		
57-100	Convocation	1
57-502	Major Studio (Organ)	9
57-4xx	Major Ensemble	6
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective Course	9
		46

Fourth Year

Fall		Units
57-100	Convocation	1
57-502	Major Studio (Organ)	9
57-4xx	Major Ensemble	6
57-xxx	Performance Elective	3
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective Course	3
		43

Spring		
57-100	Convocation	1
57-502	Major Studio (Organ)	9
57-4xx	Major Ensemble	6
57-xxx	Performance Elective	3
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective Course	3
		43

Voice

First Year

Fall		Units
57-100	Convocation	1
57-500	Major Studio (Voice)	9
57-593	Vocal Coaching	1
57-010	Voice Studio Performance Class	1
57-417	Major Vocal Performance Ensemble	6
57-467	Production: Crew	3
57-191	Keyboard Studies	3
57-152	Harmony I	9
57-161	Eurhythmics I	3
57-181	Solfege I	3
82-161	Elementary Italian I	12
99-101	Core@CMU	3
57-240	Acting I	3
57-111	Movement and Dance I	3
		60

Spring		
57-100	Convocation	1
57-500	Major Studio (Voice)	9
57-593	Vocal Coaching	1
57-010	Voice Studio Performance Class	1
57-417	Major Vocal Performance Ensemble	6
57-468	Production: Crew	3
57-192	Keyboard Studies	3
57-153	Harmony II	9
57-162	Eurhythmics II	3
57-182	Solfege II	3
82-162	Elementary Italian II	12
57-221	Italian Diction	3
57-241	Acting II	3
57-112	Movement and Dance II	3
		60

Second Year

Fall		Units
57-100	Convocation	1
57-500	Major Studio (Voice)	9
57-593	Vocal Coaching	1
57-010	Voice Studio Performance Class	1
57-417	Major Vocal Performance Ensemble	6
57-193	Keyboard Studies	3
57-163	Eurhythmics III	3
57-183	Solfege III	3
57-189	Introduction to Repertoire and Listening for Musicians	3
82-121	Elementary German I	12
76-101	Interpretation and Argument	9
57-151	Counterpoint in Theory and Application	6
57-339	Acting III	3
57-211	Movement and Dance III	3
		63

Spring		
57-100	Convocation	1
57-500	Major Studio (Voice)	9
57-593	Vocal Coaching	1
57-010	Voice Studio Performance Class	1
57-417	Major Vocal Performance Ensemble	6
57-194	Keyboard Studies	3
57-164	Eurhythmics IV	3
57-184	Solfege IV	3
57-190	Repertoire and Listening for Musicians I	3
57-283	Music History I	9
82-122	Elementary German II	12
57-223	German Diction	3
57-408	Form and Analysis	6
57-340	Acting IV	3
57-212	Movement and Dance IV	3
		66

Third Year

Fall		Units
57-100	Convocation	1
57-500	Major Studio (Voice)	9
57-593	Vocal Coaching	1
57-010	Voice Studio Performance Class	1
57-417	Major Vocal Performance Ensemble	6
57-xxx	Production Course	6
57-289	Repertoire and Listening for Musicians II	3
57-284	Music History II	9
82-101	Elementary French I	12
57-101	Introduction to Music Technology	6
57-222	French Diction	3
		57

Spring		
57-100	Convocation	1
57-500	Major Studio (Voice)	9
57-593	Vocal Coaching	1
57-010	Voice Studio Performance Class	1
57-417	Major Vocal Performance Ensemble	6
57-xxx	Production Course	6
57-290	Repertoire and Listening for Musicians III	3
57-285	Music History III	9
82-102	Elementary French II	12
		48

Fourth Year

Fall		Units
57-100	Convocation	1
57-500	Major Studio (Voice)	9
57-593	Vocal Coaching	1
57-010	Voice Studio Performance Class	1
57-417	Major Vocal Performance Ensemble	6
57-xxx	Production Course	6
57-473	Survey of Vocal Repertoire I	3
xx-xxx	Global, Cultural, and Diverse Perspectives Course	9
xx-xxx	Elective Course	3
		39

Spring		
57-100	Convocation	1
57-500	Major Studio (Voice)	9
57-593	Vocal Coaching	1
57-010	Voice Studio Performance Class	1
57-417	Major Vocal Performance Ensemble	6
57-xxx	Production Course	6
57-474	Survey of Vocal Repertoire II	3
xx-xxx	Elective Course	12
		39

Instrumental

A string major must also complete two semesters of Chamber Music in the sophomore year.

First Year

Fall		Units
57-100	Convocation	1
57-xxx	Studio	9
57-4xx	Major Ensemble	6
57-191	Keyboard Studies	3
57-152	Harmony I	9
57-161	Eurhythmics I	3
57-181	Solfege I	3
57-189	Introduction to Repertoire and Listening for Musicians	3
57-101	Introduction to Music Technology	6
99-101	Core@CMU	3
76-101	Interpretation and Argument	9
		55

Spring		
57-100	Convocation	1
57-xxx	Studio	9
57-4xx	Major Ensemble	6
57-192	Keyboard Studies	3
57-153	Harmony II	9
57-162	Eurhythmics II	3
57-182	Solfege II	3
57-190	Repertoire and Listening for Musicians I	3
57-283	Music History I	9
xx-xxx	Global, Cultural, and Diverse Perspectives Course	9
		55

Second Year

Fall		Units
57-100	Convocation	1
57-xxx	Studio	9
57-4xx	Major Ensemble	6
57-193	Keyboard Studies	3
57-151	Counterpoint in Theory and Application	6
57-163	Eurhythmics III	3
57-183	Solfege III	3
57-289	Repertoire and Listening for Musicians II	3
57-284	Music History II	9
xx-xxx	General Studies Course	6
		49

Spring		
57-100	Convocation	1
57-xxx	Studio	9
57-4xx	Major Ensemble	6
57-194	Keyboard Studies	3
57-408	Form and Analysis	6
57-164	Eurhythmics IV	3
57-184	Solfege IV	3
57-290	Repertoire and Listening for Musicians III	3
57-285	Music History III	9
xx-xxx	Elective Course	6
		49

Third Year

Fall		Units
57-100	Convocation	1
57-xxx	Studio	9
57-4xx	Major Ensemble	6
57-xxx	Chamber Music	3
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective Couirse	6
		46

Spring		
57-100	Convocation	1
57-xxx	Studio	9
57-4xx	Major Ensemble	6
57-xxx	Chamber Music	3
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective Course	6
		46

Fourth Year

Fall		Units
57-100	Convocation	1
57-xxx	Studio	9
57-4xx	Major Ensemble	6
57-xxx	Chamber Music	3
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective Course	3
		43

Spring		
57-100	Convocation	1
57-xxx	Studio	9
57-4xx	Major Ensemble	6
57-xxx	Chamber Music	3
57-xxx	Music Support Course (Theory/History)	12
xx-xxx	General Studies Course	9
xx-xxx	Elective Course	3
		43

Composition

First Year

Fall		Units
57-100	Convocation	1
57-521	Major Studio (Composition)	9
57-4xx	Major Ensemble	6
57-191	Keyboard Studies	3
57-152	Harmony I	9
57-161	Eurhythmics I	3
57-181	Solfege I	3
57-189	Introduction to Repertoire and Listening for Musicians	3
57-101	Introduction to Music Technology	6
99-101	Core@CMU	3
76-101	Interpretation and Argument	9
		55

Spring		
57-100	Convocation	1
57-521	Major Studio (Composition)	9
57-4xx	Major Ensemble	6

57-192	Keyboard Studies	3
57-153	Harmony II	9
57-162	Eurhythmics II	3
57-182	Solfege II	3
57-190	Repertoire and Listening for Musicians I	3
57-283	Music History I	9
xx-xxx	Global, Cultural, and Diverse Perspectives Course	9
		55

Second Year

Fall		Units
57-100	Convocation	1
57-521	Major Studio (Composition)	9
57-4xx	Major Ensemble	6
57-193	Keyboard Studies	3
57-151	Counterpoint in Theory and Application	6
57-163	Eurhythmics III	3
57-183	Solfege III	3
57-289	Repertoire and Listening for Musicians II	3
57-284	Music History II	9
57-257	Orchestration I	6
xx-xxx	Elective Course	6
		55

Spring		
57-100	Convocation	1
57-521	Major Studio (Composition)	9
57-4xx	Major Ensemble	6
57-194	Keyboard Studies	3
57-408	Form and Analysis	6
57-164	Eurhythmics IV	3
57-184	Solfege IV	3
57-290	Repertoire and Listening for Musicians III	3
57-285	Music History III	9
57-271	Orchestration II	6
57-258	20th-21st Century Techniques	6
		55

Third Year

Fall		Units
57-100	Convocation	1
57-521	Major Studio (Composition)	9
57-234	Performance for Composers	3
57-332	Introduction to Conducting	6
57-347	Electronic and Computer Music	6
57-xxx	Music Support Course	6
xx-xxx	General Studies Course	12
		43

Spring		
57-100	Convocation	1
57-521	Major Studio (Composition)	9
57-236	Performance for Composers	3
57-336	Instrumental/Choral Conducting	6
57-459	Score Reading for Composition Majors and Conducting Minors	6
57-xxx	Music Support Course	6
xx-xxx	General Studies Course	12
		43

Fourth Year

Fall		Units
57-100	Convocation	1
57-521	Major Studio (Composition)	9
57-4xx	Major Ensemble	6
57-xxx	Music Support Course	6
xx-xxx	General Studies Course	9
xx-xxx	Elective Course	12
		43

Spring		
57-100	Convocation	1
57-521	Major Studio (Composition)	9
57-4xx	Major Ensemble	6
57-xxx	Music Support Course	6
xx-xxx	General Studies Course	9
xx-xxx	Elective Course	6
		37

ELECTRONIC MUSIC

First Year

57-100	Convocation	1
57-560	Electronic Music Seminar	3
57-152	Harmony I	9
57-161	Eurhythmics I	3
57-181	Solfege I	3
76-101	Interpretation and Argument	9
57-358	Introduction to Electronic Music	9
99-101	Core@CMU	3
57-421	Exploded Ensemble	6
57-523	Major Studio (Electronic Music)	9
57-191	Keyboard Studies	3

57-100	Convocation	1
57-560	Electronic Music Seminar	3
57-153	Harmony II	9
57-162	Eurhythmics II	3
57-182	Solfege II	3
57-102	Twisted Signals: Multimedia Processing for the Arts	9
xx-xxx	Global, Cultural, and Diverse Perspectives Course	9
57-421	Exploded Ensemble	6
57-523	Major Studio (Electronic Music)	9
57-192	Keyboard Studies	3

Second Year

57-100	Convocation	1
57-560	Electronic Music Seminar	3
57-421	Exploded Ensemble	6
57-163	Eurhythmics III	3
57-183	Solfege III	3
57-257	Orchestration I	6
57-xxx	Music Elective	9
57-xxx	Electronic Music support course/Special Topics	9
57-523	Major Studio (Electronic Music)	9
57-193	Keyboard Studies	3

57-100	Convocation	1
57-560	Electronic Music Seminar	3
57-421	Exploded Ensemble	6
57-408	Form and Analysis	6
57-164	Eurhythmics IV	3
57-184	Solfege IV	3
57-xxx	Electronic Music support course/Special Topics	9
57-523	Major Studio (Electronic Music)	9
xx-xxx	General Studies Course	10
57-194	Keyboard Studies	3

Third Year

57-523	Major Studio (Electronic Music)	9
57-560	Electronic Music Seminar	3
57-332	Introduction to Conducting	6
15-104	Introduction to Computing for Creative Practice	10
57-xxx	Electronic Music support course/Special Topics	9
57-421	Exploded Ensemble	6

57-173	Survey of Western Music History	9
57-188	Repertoire and Listening for Musicians	1

57-523	Major Studio (Electronic Music)	9
57-560	Electronic Music Seminar	3
57-344	Experimental Sound Synthesis	9
57-359	Audiovisual Composition	9
57-xxx	Electronic Music support course/Special Topics	9
57-421	Exploded Ensemble	6
xx-xxx	General Studies Course	10

Fourth Year

57-523	Major Studio (Electronic Music)	9
57-560	Electronic Music Seminar	3
57-421	Exploded Ensemble	6
57-xxx	Electronic Music support course/Special Topics	9
xx-xxx	General Studies Course	12
57-xxx	Music Elective	9

57-523	Major Studio (Electronic Music)	9
57-560	Electronic Music Seminar	3
57-421	Exploded Ensemble	6
57-xxx	Electronic Music support course/Special Topics	6
xx-xxx	General Studies Course	9
57-xxx	Music Elective	9

Dalcroze Eurhythmics Certificate — 33 units

57-465	Eurhythmics Applications for Performing and Teaching	6
xx-xxx	Creative Movement/Choreography	3

Piano Pedagogy Certificate — 36 units

57-273	Piano Pedagogy I	6
57-274	Piano Pedagogy II	6
57-275	Piano Pedagogy III	6
57-276	Piano Pedagogy IV	6
57-429	Beginning Piano for Children I	6
57-449	Beginning Piano for Children II	6

Bachelor of Science in Music and Technology

The Bachelor of Science in Music and Technology is offered jointly by the School of Music, the School of Computer Science, and the College of Engineering.

This program consists of a set of courses that span both music and technology, as well as a capstone composition/design/performance project. Courses in all three areas of study are stipulated in the music and technology undergraduate curriculum and provide for students coming from any of the three areas. In other words, regardless of a student's entry point — an interest in computer science, electrical engineering, or music — the coursework prescribed will allow the student to gain the requisite knowledge and experience in all three areas. Students will work closely with advisors and will be guided in both course selection and capstone projects.

Curriculum

Minimum units required for B.S. in Music and Technology — 380

General Requirements — 85 units

Seminar

57-570	Music and Technology Seminar (8 semesters for a total of 8 units)	1

University

99-101	Core@CMU	3
76-101	Interpretation and Argument	9
xx-xxx	Global, Cultural, and Diverse Perspectives Course	9

Humanities

xx-xxx	Cognition, Choice and Behavior course	9
xx-xxx	English, History, Modern Languages, Philosophy, or Psychology course	9

Mathematics

21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10

Science

33-114	Physics of Musical Sound	9
33-141	Physics I for Engineering Students	12

Electives — 33 or 37 units

Music Core — 81 units

57-152	Harmony I	9
57-153	Harmony II	9
57-408	Form and Analysis	6
57-151	Counterpoint in Theory and Application	6
57-258	20th-21st Century Techniques	6
57-257	Orchestration I	6
57-189	Introduction to Repertoire and Listening for Musicians	3
57-190	Repertoire and Listening for Musicians I	3
57-289	Repertoire and Listening for Musicians II	3
57-290	Repertoire and Listening for Musicians III	3
57-181	Solfege I	3
57-182	Solfege II	3
57-183	Solfege III	3
57-184	Solfege IV	3
57-161	Eurhythmics I	3
57-162	Eurhythmics II	3
57-173	Survey of Western Music History	9

Music and Technology Core — 121 units

15-112	Fundamentals of Programming and Computer Science	12
15-122	Principles of Imperative Computation	12
15-322	Introduction to Computer Music	9
18-100	Introduction to Electrical and Computer Engineering	12
18-202	Mathematical Foundations of Electrical Engineering	12
18-290	Signals and Systems	12
57-101	Introduction to Music Technology	6
57-347	Electronic and Computer Music	6
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-438	Multitrack Recording	9
57-571	Music and Technology Project	12
57-572	Music and Technology Project	12

Concentration

Students complete either the Music Concentration or the Technical Concentration:

Music Concentration — 60 units

57-5xx	Studio (4 semesters)	36
57-4xx	Major Ensemble (4 semesters)	24

Technical Concentration — 58 or 56 units

21-127	Concepts of Mathematics	12
15/18-213	Introduction to Computer Systems	12

AND EITHER:

18-220	Electronic Devices and Analog Circuits	12
18-240	Structure and Design of Digital Systems	12
15-2xx/18-3xx or above	Electives in ECE or CS	12

OR:

15-210	Parallel and Sequential Data Structures and Algorithms	12
15-323	Computer Music Systems and Information Processing	9
15-2xx/18-3xx or above	Electives in ECE or CS	12

Minors

Minor in Collaborative Piano for Students in the School of Music

Admission Requirements:

The student must apply to enter the program in the office of the Director of Student Services (HOA 141A).

36 unitsRequired Courses

57-381	Collaborative Piano I	6
57-382	Collaborative Piano II	6
57-383	Collaborative Piano III	6
57-384	Collaborative Piano IV	6
57-385	Collaborative Piano V	6
57-386	Collaborative Piano VI	6

18 unitsElectives

(choose from the following courses)

57-220	English Diction	3
57-221	Italian Diction	3
57-222	French Diction	3
57-223	German Diction	3
57-332	Introduction to Conducting	6
57-336	Instrumental/Choral Conducting	6
57-459	Score Reading for Composition Majors and Conducting Minors	6
57-557	Vocal Methods	3

Minimum units required for Collaborative Piano Minor:	54

Minor in Conducting for Students in the School of Music

Admission Requirements:

1. The student must apply to enter the program in the office of the Director of Student Services (HOA 141A).
2. A 3.0 cumulative overall QPA and good academic standing are required.
3. In addition to passing the prerequisite courses listed below, the student must display superior solfege skills, by passing Advanced Solfege I and II with “A” or “B” grades or by passing Solfege I and II with "A" or "B" grades and with the recommendation of the student's solfege instructor; and the student must also pass Introduction to Conducting with an "A" grade or with a "B" grade and with the recommendation of the student's conducting instructor.

ACADEMIC REQUIREMENTS:

1. Immediately after acceptance into the minor in conducting, the student must schedule an advising appointment with the faculty supervisor of the conducting minor.
2. Instrumental/Choral Conducting must be completed before the senior year with an "A" grade or with a "B" grade and with the recommendation of the student's conducting instructor before the student can register for the advanced conducting courses (see #3).
3. Conducting Practicum must be taken during the same semester as Independent Study in Conducting. Both courses must be taken after completing Introduction to Conducting and Instrumental/Choral Conducting.
4. A 3.0 cumulative overall QPA is required for graduation with the minor in conducting.

30 unitsPrerequisite Courses

57-152	Harmony I	9
57-153	Harmony II	9
57-161	Eurhythmics I	3
57-162	Eurhythmics II	3
57-189	Introduction to Repertoire and Listening for Musicians	3
57-191	Keyboard Studies	3

39 unitsRequired Courses

Choose two of the following five courses immediately below as recommended by the faculty supervisor of the conducting minor:

57-360	Brass Methods	3
57-361	Percussion Methods	3
57-362	Woodwind Methods	3
57-363	String Methods	3
57-557	Vocal Methods	3

57-332	Introduction to Conducting	6
57-336	Instrumental/Choral Conducting	6
57-257	Orchestration I	6
57-459	Score Reading for Composition Majors and Conducting Minors	6
57-364	Conducting Practicum	3
57-618	Independent Study in Conducting	6

15 unitsElectives

(choose from the following courses)

57-220	English Diction	3
57-221	Italian Diction	3
57-222	French Diction	3
57-223	German Diction	3
57-258	20th-21st Century Techniques	6
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-491	Solfege for Conductors I	3
57-492	Solfege for Conductors II	3
57-227	Jazz Instrumental Ensemble	3
57-230	Baroque Ensemble	3
57-420	JIVE - CMU Jazz Choir	3
57-423	Repertoire Orchestra	3
57-675	Chamber Ensemble	3

Minimum units required for Conducting minor:	54

Minor in Music Education for Students in the School of Music

Admission Requirements:

The student must apply to the music education faculty no earlier than spring of the freshman year.

Corequisite General Courses 36 units

76-101	Interpretation and Argument	9
21-xxx	Mathematics Course #1	9
21-xxx	Mathematics Course #2	9
76-xxx	English Literature Course	9

Corequisite Music Courses 18 units

57-391	Keyboard Studies (Music Ed)	3
57-392	Keyboard Studies (Music Ed)	3
57-332	Introduction to Conducting	6
57-336	Instrumental/Choral Conducting	6

General Education Courses		18 units
57-331	Principles of Education	9
57-643	Diverse Populations in Inclusive Settings	9

Music Education Methods Courses		45 units

General Methods Courses

57-375	Music in the Elementary School	6
57-356	Elementary Guided Teaching	3
57-376	Music in the Secondary School	6
57-355	Secondary Guided Teaching	3

Applied Area Methods Courses

57-207	Music Studio	Var.
57-360	Brass Methods	3
57-361	Percussion Methods	3
57-363	String Methods	3
57-362	Woodwind Methods	3
57-557	Vocal Methods	3

Band Methods Courses

Stage Direction is optional.

57-333	Band and Choral Arranging	6
57-334	Fundamentals of Marching Band	3
57-370	Stage Direction	3

Music Education Teaching Courses		12 units
57-603	Practice Teaching (Elementary)	6
57-604	Practice Teaching (Secondary)	6

Minimum units required for Music Education Minor: 129

Minor in Music Technology for Students in the School of Music

Admission Requirements:

The student must apply to enter the program in the office of the Director of Student Services (HOA 141A).

Prerequisite Courses		18 units
57-152	Harmony I	9
57-161	Eurhythmics I	3
57-181	Solfege I	3
57-189	Introduction to Repertoire and Listening for Musicians	3

Sound Recording Courses		21 units
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-438	Multitrack Recording	9

Music Technology/Sound Courses (choose 3) — 21 units

Choose at least three courses. One of the three courses must be either Introduction to Computer Music or Electronic and Computer Music. (Note that 15-112 is a prerequisite for 15-322; 57-101 or 57-171 is a prerequisite for 57-347.) Other courses may be taken with the permission of the minor in music technology advisor.

15-104	Introduction to Computing for Creative Practice	10
15-322	Introduction to Computer Music	9
33-114	Physics of Musical Sound	9
54-166	Introduction to Sound Design for Theatre	6
54-666	Production Audio	6
57-102	Twisted Signals: Multimedia Processing for the Arts	9
57-344	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music	6
57-421	Exploded Ensemble	6
57-478	Survey of Historical Recording	6

Minimum units required for Music Technology Minor: 60

Minor in Music Theory for Students in the School of Music

Admission Requirements:

The student must apply to enter the program in the office of the Director of Student Services (HOA 141A).

Prerequisite Courses		18 units
57-152	Harmony I	9
57-161	Eurhythmics I	3
57-181	Solfege I	3
57-189	Introduction to Repertoire and Listening for Musicians	3

Upper Level Theory Courses (choose 3) — 21 units

See theory courses on the Music Support Courses Two-Year Rotation list. It is available on the Current Students website (https://www.cmu.edu/cfa/music/current-students/). A graduate course may be taken with the permission of the instructor.

Graduate Theory Courses (choose 1) — 6–9 units

See graduate theory courses on the Music Support Courses Two-Year Rotation list. It is available on the Current Students website (https://www.cmu.edu/cfa/music/current-students/). The course is to be chosen with the approval of the minor in music theory advisor.

General Education Courses		18 units
33-114	Physics of Musical Sound	9
57-377	Psychology of Music	9

Minimum units required for Music Theory Minor: 63

Sonic Arts Minor – IDeATe

Sonic Art is a creative expression that uses sound as its primary medium. Just as visual artists create landscapes, portraits, and narratives through light, color, and form, sonic artists craft transformative experiences through sound, noise, and music.

Students in the *Sonic Arts* minor explore the processes and products of digital sound design and music production. They receive basic training in key component areas: principles of computer music, sound synthesis, spatialization, and core practices in sound design. Combining this training with courses that bring together experts from many disciplines, they create experimental music and explore emerging applications and markets for sound design, music creation, and performance.

Curriculum

One Computing Course - Minimum of 9 Units

		Units
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
60-212	Intermediate Studio: Creative Coding	12

One IDeATe Portal Course - Minimum of 9 Units

		Units
18-090	Twisted Signals: Multimedia Processing for the Arts Other IDeATe Portal Course by permission only. Consult the IDeATe advisor.	10

IDeATe Sonic Arts Courses - Minimum of 27 Units

		Units
15-322	Introduction to Computer Music	9
33-114	Physics of Musical Sound	9
54-166	Introduction to Sound Design for Theatre	6
54-267	Conceptual Sound Design	9

54-509	Theatrical Sound System Design 2	9
57-337	Sound Recording	6
57-344/60-407	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music	6
57-358	Introduction to Electronic Music portfolio required for registration	9
57-359	Audiovisual Composition	9
57-421	Exploded Ensemble	6
57-458	Business of Music	6

Additional course options as available. Please refer to the IDeATe website for courses for the current and upcoming semester.

Double-Counting

Students may double-count up to two of their *Sonic Arts* minor courses for other requirements.

Part-Time Faculty

FREIDA ABTAN, Assistant Professor of Electronic Music Composition – Ph.D., Brown University; Carnegie Mellon, 2021–

CHRISTOPHER ALLEN, Artist Lecturer in Percussion – M.M. , Temple University; Carnegie Mellon, 2014–

ALBERTO ALMARZA, Associate Professor of Flute – M.F.A., Carnegie Mellon University; Carnegie Mellon, 1991–

DONNA AMATO, Artist Lecturer in Piano and Staff Pianist – B.M., University of Arizona; Carnegie Mellon, 1998–

JENNIFER AYLMER, Assistant Professor of Voice – M.M, Westminster Choir College; Carnegie Mellon, 2012–

NEAL BERNTSEN, Artist Lecturer in Trumpet – M.M., Northwestern University; Carnegie Mellon, 2003–

JOANNA BOSSE, Interim Head and Visiting Professor – Ph.D., University of Illinois; Carnegie Mellon, 2023–

JEREMY BRANSON, Artist Lecturer in Percussion – M.M., Temple University; Carnegie Mellon, 2009–

WILLIAM CABALLERO, Associate Teaching Professor in Horn – B.M., New England Conservatory; Carnegie Mellon, 2007–

ANDREW CARLISLE, Director of Piping

L. MARK CARVER, Associate Teaching Professor in Collaborative Piano – M.M., Carnegie Mellon University; Carnegie Mellon, 1995–

TATJANA CHAMIS, Artist Lecturer in Viola – B.M., Curtis Institute of Music; Carnegie Mellon, 2016–

REBECCA CHERIAN, Artist Lecturer in Trombone – M.M., Yale University; Carnegie Mellon, 1993–

FREDERIC CHIU, Assistant Professor of Piano – M.M., Juilliard; Carnegie Mellon, 2020–

DENIS COLWELL, Associate Professor – M.M., Carnegie Mellon University; Carnegie Mellon, 1980–

MARIANNE CORNETTI, Artist Lecturer in Voice – B.M., Duquesne University; Carnegie Mellon, 2019–

DANIEL CURTIS, Resident Conductor – M.M. , Carnegie Mellon University; Carnegie Mellon, 2015–

MICHELE DE LA REZA, Assistant Teaching Professor of Dance – M.S., University of Pittsburgh; Carnegie Mellon, 2007–

CYNTHIA DEALMEIDA, Associate Teaching Professor in Oboe – M.M., Temple University; Carnegie Mellon, 1991–

JEFF DEE, Artist Lecturer in Bass Trombone – M.M, The Juilliard School; Carnegie Mellon, 2017–

HIRAM DIAZ, Artist Lecturer in EuphoniumCarnegie Mellon, 2024–

MARK DOMENCIC, Artist Lecturer in Music Theory – M.M., Carnegie Mellon University; Carnegie Mellon, 2007–

THOMAS DOUGLAS, Teaching Professor of Voice – M.M., Duquesne University; Carnegie Mellon, 1991–

JOCELYN DUECK, Assistant Professor of Collaborative Piano – D.M.A., University of Minnesota; Carnegie Mellon, 2017–

PAUL EVANS, Artist Lecturer in Percussion – M.M., Temple University; Carnegie Mellon, 1995–

DONNA FOX, Artist Lecturer of Music EducationCarnegie Mellon, 2023-–

NANCY GALBRAITH, Professor of Composition – M.M., West Virginia University; Carnegie Mellon, 1984–

PAUL GERLACH, Artist Lecturer in Music Education – M.F.A., Carnegie Mellon University; Carnegie Mellon, 1982–

JAMES GORTON, Artist Lecturer in Chamber Music – B.M., Eastman School of Music; Carnegie Mellon, 2020-–

SARI GRUBER, Artist Lecturer in Voice – M.M., Juilliard School; Carnegie Mellon, 2018–

PETER GUILD, Artist Lecturer in Double Bass – M.M., University of Michigan; Carnegie Mellon, 2015–

DAVID HARDING, Associate Professor in Viola and Chamber Music – B.M., The Juilliard School; Carnegie Mellon, 2012-–

JAMES HOULIK, Artist Lecturer in Saxophone Eastman School of Music; Carnegie Mellon, 2018–

MICAH HOWARD, Artist Lecturer in Double Bass – M.M., Duquesne University; Carnegie Mellon, 2010–

JACK HOWELL, Artist Lecturer in ClarinetCarnegie Mellon, 2023-–

ANNIE HSIEH, Assistant Teaching Professor of Music Theory – Ph.D., University of California, San Diego; Carnegie Mellon, 2018-–

ROSEANNA IRWIN, Associate Teaching Professor of Coaching and Accompanying – M.M., Duquesne University; Carnegie Mellon, 1990–

JOHN PAUL ITO, Assistant Professor of Music Theory – Ph.D., Columbia University; Carnegie Mellon, 2011–

PAUL JOHNSTON, Artist Lecturer in Music History – B.M.E., Andrews University; Carnegie Mellon, 2005–

KENNETH KEELING, Associate Head and Professor Emeritus of Music – D.M.A., Catholic University of America; Carnegie Mellon, 1996–

ADRIANNE DAVIS KELLY, Artist Lecturer of Music Education Duquesne University; Carnegie Mellon, 2019–

SUNG-IM KIM, Staff Pianist – M.M., Carnegie Mellon University; Carnegie Mellon, 2011–

CRAIG KNOX, Artist Lecturer in Tuba – B.M., Curtis Institute of Music; Carnegie Mellon, 2005–

PETER KOPE, Assistant Teaching Professor of Dance University of Dayton; Carnegie Mellon, 2007–

STEPHEN KOSTYNIAK, Artist Lecturer in French Horn – B.M., The Juilliard School; Carnegie Mellon, 2008–

JASON KUSH, Artist Lecturer in Saxophone – D.M.A., University of Miami; Carnegie Mellon, 2017–

CARLA LAROCCA, Associate Teaching Professor of Keyboard Studies – M.F.A., Carnegie Mellon University; Carnegie Mellon, 1991–

ELIZABETH LAWRENCE, Artist Lecturer in Jazz Voice and Director of Jazz Vocal Ensemble – M.M., Manhattan School of Music; Carnegie Mellon, 1996–

VICTORIA LUPERI, Artist Lecturer in ClarinetCarnegie Mellon, 2024-–

LUZ MANRIQUEZ, Associate Teaching Professor in Collaborative Piano – M.M., Carnegie Mellon University; Carnegie Mellon, 1992–

JOHN MARCINIZYN, Artist Lecturer in Guitar and Composition – Ph.D., University of Pittsburgh; Carnegie Mellon, 1991–

DAVID MCCARROLL, Artist Lecturer in ViolinCarnegie Mellon, 2024-–

LORNA MCGHEE, Artist Lecturer in Flute Royal Scottish Academy of Music and Drama; Carnegie Mellon, 2015–

MONIQUE MEAD, Director of Music Entrepreneurial Studies – M.M., Indiana University-Bloomington; Carnegie Mellon, 2012–

ANNE MOSKAL, Artist Lecturer in Solfege – M.M., Carnegie Mellon University; Carnegie Mellon, 2011–

STEPHEN NEELY, Artist Lecturer in Eurhythmics – M.M., Carnegie Mellon University; Carnegie Mellon, 1998–

RODRIGO OJEDA, Assistant Teaching Professor of Collaborative Piano – M.M., Carnegie Mellon University; Carnegie Mellon, 2011–

JEREMY OLISAR, Artist Lecturer in Music EducationCarnegie Mellon, 2021–

BENJAMIN OPIE, Artist Lecturer in Music Technology – M.M., Duquesne University; Carnegie Mellon, 2005–

PHILIP PANDOLFI, Artist Lecturer in Bassoon – M.M., Temple University; Carnegie Mellon, 2024–

DIMITRI PAPADIMITRIOU, Assistant Teaching Professor of Chamber Music and Piano – D.M.A., Royal Irish Academy of Music; Carnegie Mellon, 2015–

ANGELA PARK, Adjunct InstructorCarnegie Mellon, 2023–

RYAN PRENDERGAST, Assistant Teaching Professor – Ph.D., University of Illinois; Carnegie Mellon, 2022–

KATHERINE PUKINSKIS, Assistant Professor of Composition and Theory – Ph.D., University of Chicago; Carnegie Mellon, 2022–

RICHARD RANDALL, Assistant Professor of Music Theory – Ph.D., Eastman School of Music; Carnegie Mellon, 2008–

SUSAN RAPONI, Assistant Professor of Music – Ph.D., University of Toronto; Carnegie Mellon, 2019–

VAHAN SARGSYAN, Staff Pianist – M.M, Yerevan Komitas State Conservatoire;

SERGEY SCHEPKIN, Associate Professor of Piano – D.M.A., New England Conservatory; Carnegie Mellon, 2003–

STEPHEN SCHULTZ, Associate Teaching Professor of Music History and Flute – M.M., San Francisco State University; Carnegie Mellon, 2002–

RICCARDO SCHULZ, Associate Teaching Professor and Director of Recording Activities – M.A., University of Pittsburgh; Carnegie Mellon, 1988–

FRANCO SCIANNAMEO, Associate Teaching Professor of Film Musicology and CFA Associate Dean – D.M, Conservatorio di Musica, Santa Cecilia; Carnegie Mellon, 2014–

MARK SNYDER, Director of Jazz Orchestra – M.M., Carnegie Mellon University; Carnegie Mellon, 2022–

MARIA SPACAGNA, Associate Professor of Voice – M.M., New England Conservatory; Carnegie Mellon, 2012–

SARAH STERANKA, Woodwind & Mixed Chamber Music Coordinator – M.M., Duquesne University; Carnegie Mellon, 2023–

STEPHEN STORY, Associate Conductor of Wind Ensemble – M.M., Carnegie Mellon University; Carnegie Mellon, 2015–

PETER SULLIVAN, Artist Lecturer in Trombone Aspen School of Music; Carnegie Mellon, 2000–

DANIEL TEADT, Artist Lecturer in Voice – M.M, University of Illinois; Carnegie Mellon, 2011–

KELLY TRUMBULL, Artist Lecturer in Acting – M.A., New York University; Carnegie Mellon, 2015–

WILLIAM VAN DER SLOOT, Assistant Teaching Professor of Violin – Diploma, International Institute for Chamber Music; Carnegie Mellon, 2017–

GRETCHEN VAN HOESEN, Artist Lecturer in Harp – M.M., The Juilliard School; Carnegie Mellon, 1985–

GEORGE VOSBURGH, Artist Lecturer in Trumpet and Co-Director of Wind Ensemble – B.A., University of Rochester; Carnegie Mellon, 2003–

JANE WALL, ArtistLecturer in Elementary Education

JAMES WHIPPLE, Artist Lecturer in Music Theory – B.A., Carnegie Mellon University; Carnegie Mellon, 1995–

ANNE MARTINDALE WILLIAMS, Artist Lecturer in Cello – Diploma, Curtis Institute of Music; Carnegie Mellon, 1987–

ALEXA WOLOSHYN, Assistant Professor of Musicology – Ph.D, University of Toronto; Carnegie Mellon, 2016–

CHRISTOPHER WU, Artist Lecturer in Violin – B.A., Eastman School of Music; Carnegie Mellon, 2009–

LENNY YOUNG, Artist Lecturer in Solfege – M.M., Carnegie Mellon University; Carnegie Mellon, 2015–

MONICA YUNUS, Artist Lecturer in Voice Entrepreneurship – M.M., The Juilliard School; Carnegie Mellon, 2018–

School of Music Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

57-010 Voice Studio Performance Class

Fall and Spring: 1 unit
Vocal Studio Performance Class is a required class for both undergraduate and graduate voice majors. Each student must participate in two singing rotations each semester and will receive written comments from the voice faculty. Students are also required to attend four studio classes each semester. Grading is pass/fail based on attendance.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-015 Violin Studio Performance Class

Fall and Spring: 1 unit
Once a week throughout the semester a "violin studio performance class" takes place. A studio class is a most important performance opportunity as it is a step between the studio lessons and the concert stage. Students perform the repertoire they are working on in front of the class and Prof. Forough. Along with comments from the class, Prof. Forough works one on one with each student. The repertoire performed can be solo pieces or accompanied pieces. This class is for violin majors who are studying with Prof. Forough. Other students may audit the class.

57-016 Viola Studio Performance Class

Fall and Spring: 1 unit
TBA

57-018 Double Bass Studio Performance Class

Fall and Spring: 1 unit
TBA

57-020 Flute Studio Performance Class

Fall and Spring: 1 unit
TBA

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-021 Oboe Studio Performance Class

Fall and Spring: 1 unit
TBA

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-022 Clarinet Studio Performance Class

Fall and Spring: 1 unit
The purpose of this class is to perform before an audience (studio class members) to ease performance anxiety. The class meets once a week. In addition to playing, the class listens to recordings of various styles of clarinet playing.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-023 Bassoon Studio Performance Class

Fall and Spring: 1 unit
TBA

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-030 Percussion Studio Performance Class

Fall and Spring: 1 unit
TBA

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-100 Convocation

Fall and Spring: 1 unit
A weekly meeting for all music students that features lectures, concerts, and other presentations related to professional development.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-101 Introduction to Music Technology

Fall and Spring: 6 units
This course gives an overview of music technology through practical information and several hands-on projects. Concepts such as MIDI and digital audio are introduced and specific topics are covered in detail including sequencing, music notation, digital recording, mixing, and production. Throughout the course, students are required to complete several projects and create musical compositions in styles of their own choosing. The student is not graded on the "musicality" of these compositions, but instead on how well they meet the stated project goals by correctly using specific equipment and/or computer programs.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-102 Finale

Spring: 6 units
This course provides hands-on and in-depth instruction of the Finale music notation program by Coda Music Software. Students will learn how to efficiently use the various notation tools that Finale has to input, edit, and manipulate music. MIDI input, playback, and transcription will also be covered to allow students to quickly notate and hear their music. The goal is to create professional-looking printed scores and parts in a variety of styles from Classical to Contemporary. Open to music majors only except by instructor permission. Introduction to Music Technology (57801/871) or equivalent experience required.
Prerequisites: 57-171 or 57-101

57-103 Elective Studio (Beginning Piano Class)

Fall and Spring: 3 units
TBA

57-104 Elective Studio (Beginning Piano Class)

Spring: 3 units
To be determined

57-109 Elective Studio (Guitar Class)

Fall and Spring: 3 units
Using classical and jazz guitar methods, this course is designed to provide a basic set of techniques that will allow students to pursue the avenue of guitar playing that most interests them. While emphasis will be on developing skills in playing the guitar, a basic understanding of the principles of music theory as applied to the guitar will also be acquired. While few students will find it possible to master all of the materials presented, an exposure to the many possibilities of musical expression available on the guitar and an understanding of basic music theory will help to broaden the students' perspective and make future musical experiences, such as listening and performing, more rewarding. Each student is expected to have his/her own instrument. A guitar in good working condition is essential. An acoustic classical or steel string is preferred, an electric with a small battery operated amp is acceptable. Students having no previous training on the guitar will find this class most valuable.

57-110 Elective Studio (Voice Class)

Fall and Spring: 3 units
Students enrolled in group voice will gain an understanding of basic vocal technique and a variety of singing styles. Students will learn about proper breathing, tone production and posture. Vocal styles will include pop, jazz, musical theater and classical. Students will also explore harmonization, improvisation and audition techniques for the singer. This class is geared towards the beginning student.

57-111 Movement and Dance I

Fall: 3 units
The CMU School of Music movement curriculum is designed to expose students to various styles and genres of contemporary and traditional forms of dance and movement. Students will increase their technical proficiency and personal artistry in dance in order to expand their physical skills as vocal performance artists. Courses will: Improve students' posture and strength, Increase proficiency in dance vocabulary, Increase ability to recognize, interpret and execute choreography, movement and staging direction, Enhance kinesthetic awareness and physical confidence and Improve overall health. With a focus on creativity and expression in movement, these courses concentrate on using the body as a tool in the creative process. Throughout "Movement and Dance I - IV", courses will include movement fundamentals, modern dance, ballet, partnering, dance composition/improvisation; as well as mini-courses in dance forms which can include stage combat, Flamenco dance, pilates and ballroom dance.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-112 Movement and Dance II

Spring: 3 units
The CMU School of Music movement curriculum is designed to expose students to various styles and genres of contemporary and traditional forms of dance and movement. Students will increase their technical proficiency and personal artistry in dance in order to expand their physical skills as vocal performance artists. Courses will: Improve students' posture and strength, Increase proficiency in dance vocabulary, Increase ability to recognize, interpret and execute choreography, movement and staging direction, Enhance kinesthetic awareness and physical confidence and Improve overall health. With a focus on creativity and expression in movement, these courses concentrate on using the body as a tool in the creative process. Throughout "Movement and Dance I - IV", courses will include movement fundamentals, modern dance, ballet, partnering, dance composition/improvisation; as well as mini-courses in dance forms which can include stage combat, Flamenco dance, pilates and ballroom dance.
Prerequisite: 57-111

57-149 Basic Harmony I

Fall: 9 units
This course deals with common-practice harmony. It includes triads and their inversions, tonality and modality, non-harmonic tones, cadences, and the basic concepts of modulation. Section assignment is determined by a placement test. It includes work on fundamentals for inexperienced students.

Course Website: https://www.andrew.cmu.edu/user/johnito/music_theory/harmony1and2/HarmMain.html

57-150 Basic Harmony II

Spring: 9 units
This course deals with common-practice harmony. It includes triads and their inversions, tonality and modality, non-harmonic tones, cadences, and the basic concepts of modulation. It includes work on fundamentals for inexperienced students.
Prerequisite: 57-149

Course Website: https://www.andrew.cmu.edu/user/johnito/music_theory/harmony1and2/HarmMain.html

57-151 Counterpoint in Theory and Application

Fall: 6 units
In Counterpoint in Theory and Application, students begin by learning the traditional five species of counterpoint in a tonal context. They then build on this foundation, learning to analyze music in terms of the underlying counterpoint and to apply this analysis to performance, and producing original tonal compositions in two voices.
Prerequisites: 57-150 or 57-153

Course Website: https://www.andrew.cmu.edu/user/johnito/music_theory/CTP/CTPMain.html

57-152 Harmony I

Fall: 9 units
This course deals with common-practice harmony. It includes triads and their inversions, tonality and modality, non-harmonic tones, cadences, and the basic concepts of modulation. Section assignment is determined by a placement test.

Course Website: https://www.andrew.cmu.edu/user/johnito/music_theory/harmony1and2/HarmMain.html

57-153 Harmony II

Spring: 9 units
This course is a continuation of the study of common practice harmony, exploring dissonant and chromatic harmony.
Prerequisite: 57-152

Course Website: https://www.andrew.cmu.edu/user/johnito/music_theory/harmony1and2/HarmMain.html

57-161 Eurhythmics I

Fall: 3 units
Dalcroze Eurhythmics is a unique approach to music learning based on the recognition that meaningful rhythmic movement experience, associated with ear-training and improvisation, reinforces understanding of music concepts, enhances musicianship, and focuses awareness on the physical demands of artistic performance. All concepts are experienced in a musical context. Rhythm reading, notation, analysis, and improvisation are integral to the course. Eurhythmics I covers basic binary and ternary metric units and rhythm patterns in relation to these metric units within simple and compound meters.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-162 Eurhythmics II

Spring: 3 units
Eurhythmics II introduces combinations of binary and ternary metric units, mixed meters, changing meters, and notation and performance of cross-rhythms.
Prerequisite: 57-161

57-163 Eurhythmics III

Fall: 3 units
Eurhythmics is a unique approach to music learning developed by the Swiss composer and educator Emile Jaques-Dalcroze (1865-1950). Dalcroze discovered that meaningful rhythmic movement experiences away from their instrument allows students to focus awareness on the physical demands of artistic performance while demonstrating knowledge and understanding of the expressive/interpretive as well as the theoretical aspects of music. Sight reading, conducting, notation, analysis and improvisation are integral to the course. Eurhythmics III Course Content: Divisive vs Additive rhythm, Metric transformation, Irregular subdivisions of metric units, Cross rhythms of 3 against 4, 3 against 5, 4 against 5.
Prerequisite: 57-162

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-164 Eurhythmics IV

Spring: 3 units
Eurhythmics is a unique approach to music learning developed by the Swiss composer and educator Emile Jaques-Dalcroze (1865-1950). It is a process for awakening, developing and refining innate musicality through rhythmic movement, ear training and improvisation. Through rhythmic movement, students demonstrate knowledge and understanding of the expressive/interpretive as well as the metrical/structural aspects of music. Sight reading, conducting, notation, analysis and improvisation are integral to the course. Eurhythmics IV Course Content: More complex rhythmic problems encountered in composed music, Changing meters and changing metric units within a composition, Rhythm reading of patterns using small note values, Messiaen rhythm techniques.
Prerequisite: 57-163

57-171 Introduction to Music Technology (self-paced)

Fall and Spring: 6 units
This course gives an overview of music technology through practical information and several hands-on projects. Concepts such as MIDI and digital audio are introduced and specific topics are covered in detail including sequencing, music notation, digital recording, mixing, and production. Throughout the course, students are required to complete several projects and create musical compositions in styles of their own choosing. The student is not graded on the "musicality" of these compositions, but instead on how well they meet the stated project goals by correctly using specific equipment and/or computer programs. This is a self-paced version of 57-101. Material will be covered during weekly class sessions, though students are expected to make time in the evenings or weekends to work on their projects in either the MTC (MM119A) or some other cluster. Students with prior experience may pass out of certain classes and projects by providing teacher with equivalent work (pending teacher approval). In addition to the required projects, there is a final exam which is administered during the last class session.

57-173 Survey of Western Music History

Fall and Summer: 9 units
This course surveys the development and contexts of European art music and its global adaptation. While keeping in view the chronology from Gregorian chant to the present, this survey emphasizes key personalities and issues, particularly issues relating to period style and interpretive decisions in performance.

Course Website: https://cmu.app.box.com/files/1/f/9350209729/1/f_33705395781 (https://cmu.app.box.com/files/1/f/9350209729/1/f_33705395781/)

57-180 Basic Solfege I

Fall: 3 units
This course improves the student's ability to analyze music aurally and to sing at sight in traditional meters and tonalities using the "fixed do" system. Solfege is the integration of the three cognitive skills: reading music, hearing music, and writing what one hears. Section assignment is determined by a placement test. It includes work on fundamentals for inexperienced students.

57-181 Solfege I

Fall: 3 units
This course improves the student's ability to analyze music aurally and to sing at sight in traditional meters and tonalities using the "fixed do" system. Solfege is the integration of the three cognitive skills: reading music, hearing music, and writing what one hears. Section assignment is determined by a placement test.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-182 Solfege II

Spring: 3 units
Continues 57-181 Solfege I.
Prerequisites: 57-181 or 57-180

57-183 Solfege III

Fall: 3 units
Continues 57-182 Solfege II. Students are given assignments of classical music written in the treble, bass, soprano, alto, and tenor clefs. Writing consists of two-part contrapuntal dictations.
Prerequisite: 57-182

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-184 Solfege IV

Spring: 3 units
Continues 57-183 Solfege III. Students learn to read atonal music and practice three-part contrapuntal dictations as well as harmonic dictations.
Prerequisite: 57-183

57-185 Advanced Solfege I

Fall: 3 units
This course improves the student's ability to analyze music aurally and to sing at sight in traditional meters and tonalities using the "fixed do" system. Solfege is the integration of the three cognitive skills: reading music, hearing music, and writing what one hears. Section assignment is determined by a placement test. It includes advanced work for experienced students and those with perfect pitch.

Course Website: https://cmu.app.box.com/files/0/f/11681158556/1/f_106285566497 (https://cmu.app.box.com/files/0/f/11681158556/1/f_106285566497/)

57-186 Advanced Solfege II

Spring: 3 units
Continues 57-185 Advanced Solfege I.
Prerequisite: 57-185

57-188 Repertoire and Listening for Musicians

Fall and Summer: 1 unit
This course is the required listening component for Survey of Western Music History (57-173). In this course, students listen critically to essential music which has stood the test of time and to superior performances. It features 2-3 hours of listening per week.

57-189 Introduction to Repertoire and Listening for Musicians

Fall: 3 units
One of the most important ways of achieving musical excellence is to listen. In this course, students listen critically to essential music which has stood the test of time and to superior performances. This on-line course features listening and discussion in a virtual coffee shop atmosphere. 2-3 hours of listening per week. Midterm and final listening tests. Proficiency requirement for freshman music majors.

57-190 Repertoire and Listening for Musicians I

Spring: 3 units
One of the most important ways of achieving musical excellence is to listen. In this course, students listen critically to essential music which has stood the test of time and to superior performances. This on-line course features listening and discussion in a virtual coffee shop atmosphere. 2-3 hours of listening per week. This semester introduces full scores for chamber and orchestral music. Midterm and final listening tests. This course contains midterm and final listening tests. Proficiency requirement for freshman music majors. Other students admitted with instructor's permission.

57-191 Keyboard Studies

Fall and Spring: 3 units
All undergraduate music students are required to take four semesters of keyboard studies during their freshman and sophomore years. The emphasis of this course is to develop a practical keyboard facility, which includes keyboard theory and technique, sightreading, solo and ensemble repertoire, transposition, and a variety of creative activities such as harmonization and improvisation.

57-192 Keyboard Studies

Fall and Spring: 3 units
All undergraduate music students are required to take four semesters of keyboard studies during their freshman and sophomore years. The emphasis of this course is to develop a practical keyboard facility, which includes keyboard theory and technique, sightreading, solo and ensemble repertoire, transposition, and a variety of creative activities such as harmonization and improvisation.
Prerequisite: 57-191

57-193 Keyboard Studies

Fall: 3 units
All undergraduate music students are required to take four semesters of keyboard studies during their freshman and sophomore years. The emphasis of this course is to develop a practical keyboard facility, which includes keyboard theory and technique, sightreading, solo and ensemble repertoire, transposition, and a variety of creative activities such as harmonization and improvisation.
Prerequisite: 57-192

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-194 Keyboard Studies

Spring: 3 units
All undergraduate music students are required to take four semesters of keyboard studies during their freshman and sophomore years. The emphasis of this course is to develop a practical keyboard facility, which includes keyboard theory and technique, sightreading, solo and ensemble repertoire, transposition, and a variety of creative activities such as harmonization and improvisation.
Prerequisite: 57-193

57-196 Collaborative Piano Skills I

Fall: 3 units
A required course for first year piano majors. The skills include sightreading, basic keyboard harmony, transposition, and improvised accompaniments for popular or musical theater songs from either a piano reduction or a lead sheet. The students participate in collaborative situations such as juries, recitals, and class presentations. The presentations are critiqued by the instructor and by other students.

57-197 Collaborative Piano Skills II

Spring: 3 units
No course description provided.
Prerequisite: 57-196

57-207 Music Studio

Fall
Provides the opportunity for students to pursue study in a secondary instrument or area. By special permission only.

57-208 Music Studio

Spring
Provides the opportunity for students to pursue study in a secondary instrument or area. By special permission only.

57-209 The Beatles

Intermittent: 6 units
This course will focus on the phenomenon of the Beatles. Their songs will be studied, with analysis of the musical and lyrical content and structural elements. What musical styles do the songs address? What were their musical influences? In what ways did their music change over the years? Also, the music's social context will be studied. Why were the Beatles so popular and influential? What exactly caused Beatlemania? How did the group form, grow, and end? The Beatles are the most famous rock group in history; the reasons for this are as much cultural as musical, and we'll study the two elements simultaneously. Open to all undergraduate students.

Course Website: https://cmu.app.box.com/files/0/f/11681158556/1/f_106285571361 (https://cmu.app.box.com/files/0/f/11681158556/1/f_106285571361/)

57-211 Movement and Dance III

Fall: 3 units
The CMU School of Music movement curriculum is designed to expose students to various styles and genres of contemporary and traditional forms of dance and movement. Students will increase their technical proficiency and personal artistry in dance in order to expand their physical skills as vocal performance artists. Courses will: Improve students' posture and strength, Increase proficiency in dance vocabulary, Increase ability to recognize, interpret and execute choreography, movement and staging direction, Enhance kinesthetic awareness and physical confidence and Improve overall health. With a focus on creativity and expression in movement, these courses concentrate on using the body as a tool in the creative process. Throughout "Movement and Dance I - IV", courses will include movement fundamentals, modern dance, ballet, partnering, dance composition/improvisation; as well as mini-courses in dance forms which can include stage combat, Flamenco dance, pilates and ballroom dance.
Prerequisite: 57-112

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-212 Movement and Dance IV

Spring: 3 units
The CMU School of Music movement curriculum is designed to expose students to various styles and genres of contemporary and traditional forms of dance and movement. Students will increase their technical proficiency and personal artistry in dance in order to expand their physical skills as vocal performance artists. Courses will: Improve students' posture and strength, Increase proficiency in dance vocabulary, Increase ability to recognize, interpret and execute choreography, movement and staging direction, Enhance kinesthetic awareness and physical confidence and Improve overall health. With a focus on creativity and expression in movement, these courses concentrate on using the body as a tool in the creative process. Throughout "Movement and Dance I - IV", courses will include movement fundamentals, modern dance, ballet, partnering, dance composition/improvisation; as well as mini-courses in dance forms which can include stage combat, Flamenco dance, pilates and ballroom dance.
Prerequisite: 57-211

57-213 Let's Dance

Intermittent: 3 units
Whether you have studied dance, are a performer, dance enthusiast or just ready to move, "Let's Dance" is a new course open to the CMU community. Ready to step away from your computer and start your day with physicality, creativity, and new ways of moving? "Let's Dance" offers a joyful approach to a variety of dance styles. Integrating concepts of modern/contemporary, ballet, improvisation, jazz and more; this class is open to all abilities and levels of movers. "Let's Dance" will build strength, flexibility, coordination and creative thinking in a collaborative and approachable learning environment.

57-220 English Diction

Fall: 3 units
This one semester course helps singers sing English songs from the Classical and Musical Theater repertoire with clarity, accuracy, ease, uniformity, and expressiveness; to illuminate meaning; and to improve tonal quality through diction.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-221 Italian Diction

Fall: 3 units
A study of the fundamentals of Italian diction and development of legato vocal style through the analysis of grammatical usage, word construction, vowel colorization, and consonant articulation. Included are in-class performance evaluations, listening assignments, critiques, and private coachings.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-222 French Diction

Fall: 3 units
This course is designed primarily for singers specializing in French Art Songs of the 19th and 20th centuries. It deals with the use of the International Phonetic Alphabet, its application to singing in French, the use of the liason and the preparation of the text of a song or aria. One-third of the course is theory and two-thirds of the course is spent on application by performance with piano accompaniment.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-223 German Diction

Fall: 3 units
In-depth study of German diction - development of legato vocal style in German through the analysis of grammatical usage, word construction, vowel colorization and consonant articulation. Included are in-class German diction evaluations, peer assessment, and emphasis on competency in using the International Phonetic Alphabet.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-226 Jazz Improvisation and Performance

Fall and Spring: 3 units
This course provides students, both music and non-music majors, with the tools and techniques for jazz improvisation that enables them to progress toward an intermediate to advanced level. Analysis of harmonic and melodic materials, extensive listening and performance exercises will assist the student in his/her development as an improvisor. The course will culminate in a performance of small group/combo pieces on the Jazz Orchestra concert. Students need to audition by performing a jazz etude or standard of their choice and demonstrate any improvisational skills they might have. Please contact the jazz orchestra director at ms86@andrew.cmu.edu to set up an audition.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-227 Jazz Instrumental Ensemble

Fall and Spring: 3 units
This ensemble incorporates a comprehensive approach to Big Band performance and study. The music performed is drawn from all eras of big band repertoire with occasional programs of specific composers and genres. The ensemble is carefully coordinated with the Jazz Vocal Ensemble and major ensembles in order to challenge and prepare students for professional music career opportunities. The ensemble performs on the regular School of Music concert series (2-3 shows per semester) and for on-campus events. Admission of undergraduate and graduate students is by competitive audition and placement is by the director. Grading is based on attendance, preparation, and consistent progress.
Prerequisite: 57-227

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-230 Baroque Ensemble

Fall and Spring: 3 units
Carnegie Mellon Baroque is a performing ensemble of 15-25 players consisting of winds, strings and keyboard. Students in this ensemble explore the orchestral and chamber music of the 18th Century. The Ensemble performs on modern instruments, incorporating performance practice ideals of the Baroque era. Throughout the rehearsal process, students are encouraged to study original source materials and arrive at historically informed and musically satisfying performances.

57-232 Chamber Music: Guitar

Fall and Spring: 3 units
Provides an opportunity for students to play in small ensembles, advised by faculty coaches. The performers will develop effective rehearsal techniques, explore chamber music repertoire, deal with issues of intonation and balance, and arrive at interpretive conclusions that are stylistically sound, yet individualistic and creative.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-234 Performance for Composers

Fall: 3 units
This course is for composition majors who choose to fulfill the performance elective requirement in the junior year by completing an independent performance project in the fall semester. Examples of projects can include producing a recital of his/her compositions, or pursuing other performing interests, such as writing music for a School of Drama production. Registration by composition faculty permission only.

57-236 Performance for Composers

Spring: 3 units
This course is for composition majors who choose to fulfill the performance elective requirement in the junior year by completing an independent performance project in the spring semester. Examples of projects can include producing a recital of his/her compositions, or pursuing other performing interests, such as writing music for a School of Drama production. Registration by composition faculty permission only.
Prerequisite: 57-234

57-240 Acting I

Fall: 3 units
The basics of acting will be established throughout the first year following the guideposts described in Audition, by Michael Shurtleff and #237;s. Structured improvisations, monologues, scene work, songs, and arias will provide a platform for the development of stage presence and effective communication. Each semester will finish with a group project that provides an opportunity for the students to begin to work together as a cast.

Course Website: https://cmu.app.box.com/files/0/f/11681158556/1/f_106285564193 (https://cmu.app.box.com/files/0/f/11681158556/1/f_106285564193/)

57-241 Acting II

Spring: 3 units
Continues 57-240 Acting I.
Prerequisite: 57-240

57-257 Orchestration I

Fall: 6 units
This is an introductory course for all music majors and required for sophomore composition majors. The characteristics of each instrument of the orchestra are studied thoroughly. Orchestral textures from the classics to contemporary music are studied and analyzed.
Prerequisites: 57-150 or 57-153

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-258 20th-21st Century Techniques

Spring: 6 units
This course is open to all music majors and required for sophomore composition majors. The most important techniques from Debussy to the present will be reviewed in terms of melody, harmony, and form. Tonality, serialism, and aleatoric devices will be studied. Compositional techniques of the 20th Century are put into perspective and compared with other developments in the arts. The class is conducted as an open forum in which discussions are encouraged.
Prerequisite: 57-151

57-271 Orchestration II

Fall: 6 units
Students will analyze music from the Classical to Avant-Garde and use the knowledge acquired to orchestrate piano scores in the appropriate style. Style, practicality, color, and imagination are encouraged. This course is designed for junior composition majors. Other students may register with instructor permission after an interview.
Prerequisite: 57-257

57-273 Piano Pedagogy I

Fall: 6 units
This course offers an historical overview of piano pedagogy including its significant developments over the past forty years. Topics covered include beginning piano techniques, the sequencing of concepts and materials, common problems among beginning pianists, practicing, motivation, and parental involvement. Current representative beginning piano methods will be surveyed.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-274 Piano Pedagogy II

Spring: 6 units
Beyond the beginning years: this course covers piano pedagogy of intermediate and early advanced level students. Topics include "What is a good piece?" Standard literature and technical development repertoire lists will be studied. The business of piano teaching and the instruction of college keyboard skills for non-piano majors will be discussed.
Prerequisite: 57-273

57-275 Piano Pedagogy III

Fall: 6 units
Continuation of 57-274. Intermediate literature, analysis, teaching, and performance will be covered. Topics include "What is style?"
Prerequisite: 57-274

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-276 Piano Pedagogy IV

Spring: 6 units
Continuation of 57-275. Early advanced literature, analysis, teaching, and performance will be covered.
Prerequisite: 57-275

57-283 Music History I

Spring: 9 units
This class will be an in-depth analytical study of music of the Medieval, Renaissance, and Baroque Periods. It will emphasize selected genres and forms by representative composers in order to trace the evolution of musical style and to clarify the main characteristics of these periods, to set the musical developments in broader cultural contexts, and to apply this knowledge to practical decisions made by today's musician.

57-284 Music History II

Fall: 9 units
This class will be an in-depth analytical study of music of the Classical and Romantic periods. It will emphasize selected genres and forms by representative composers in order to trace the evolution of musical style, to clarify the main characteristics of these periods, to set the musical developments in broader cultural contexts, and to apply this knowledge to practical decisions made by today's musician.
Prerequisite: 57-283

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-285 Music History III

Spring: 9 units
This class will be an in-depth analytical study of music from the 20th and 21st centuries. It will emphasize selected genres and approaches by representative composers in order to trace the various threads of musical style, to clarify the main characteristics of the period's music, to set the musical developments in broader cultural contexts, and to apply this knowledge to the lives and musical practices of musicians today.
Prerequisites: 57-283 and 57-284

57-289 Repertoire and Listening for Musicians II

Fall: 3 units
This is a continuation of the School of Music's four-semester listening curriculum. Students listen critically to essential music which has stood the test of time and to superior performances. This semester's repertoire includes units focusing on contrapuntal masterpieces from the Middle Ages through 20th Century, and further builds score-reading experience. This on-line course features listening and discussion in a virtual coffee shop atmosphere. 2-3 hours of listening per week. Midterm and final listening tests. Proficiency requirement for sophomore music majors. Other students admitted with instructor's permission. Repertoire and Listening for Musicians I and II are not prerequisites.

57-290 Repertoire and Listening for Musicians III

Spring: 3 units
This is the culmination of the School of Music's four-semester listening curriculum. Students listen critically to essential music which has stood the test of time and to superior performances. Highlights of this semester's repertoire include units on Middle and Late Beethoven as well as a decade-by-decade survey of the 20th Century. This on-line course features listening and discussion in a virtual coffee shop atmosphere. 2-3 hours of listening per week. Midterm and final listening tests. Proficiency requirement for sophomore music majors. Other students admitted with instructor's permission. Repertoire and Listening for Musicians I-III are not prerequisites.

57-299 Bagpipe and Drum Band

Fall and Spring
TBD

57-300 Advanced Bagpipe and Drum Band

Fall and Spring: 6 units
The Pipe Band at Carnegie Mellon is a competitive Grade 3 band in the Eastern United States Pipe Band Association. The band competes at various Scottish festivals and Highland Games during the school year. The band also performs at university activities throughout the year. These include Convocation, Homecoming, Spring Carnival, and Commencement. Other engagements are Spring Concert at CMU and the St. Patrick's Day Parade in Pittsburgh. The band has also played as an opening act for the Pittsburgh Steelers and a Rod Stewart concert.
Prerequisite: 57-299

57-301 Bagpipe History

Intermittent: 3 units
This course covers all types of bagpipe music, including Ceol Mor and Ceol Beag, and studies the prominent composers from MacCrimmon to the present day. Students compose their own material in all time signatures commonly used. The course covers Piobaireachd, Marches, Strathspeys, Reels, Hornpipes, and Jigs, as well as harmony and the ability to write out tunes from repetitive listening.

57-303 Bagpipe Literature and Repertoire

Intermittent: 3 units
This course will cover the origins of the bagpipe and Piobaireachd, bagpipe music in competition, military, and dance. We will also cover major piping competitions, famous bagpipe players, and piping today.

57-304 Bagpipe Maintenance

Intermittent: 3 units
All aspects of bagpipe maintenance are covered in this course, from basic hemping and tying in bags to reeds set-up and manipulation. The course includes study of all types of reeds, cane and synthetic, as well as drone and chanter, and recognition of pipemakers' patterns and distinctive hallmarks.

57-305 Bagpipe Reedmaking

Intermittent: 3 units
This is a hands-on course where the student learns how to make pipe chanter reeds by the traditional method of gouging, shaping, and tying up. This course follows 57-304, Bagpipe Maintenance. Further analysis of chanter and drone reeds will be covered also.
Prerequisite: 57-304

57-306 World Music

Intermittent: 9 units
A study of major musical traditions from around the world, including classical music from Asia (broadly defined) and the Middle East, as well as traditional musics in Africa, Europe, and the Americas. This course will examine music in its socio-cultural context, and will demonstrate how learning about music from diverse cultures increases cross-cultural understanding. This course will engage with readings, listening examples, multi-media presentations, in-class discussions, music-making activities, and special guests (virtual and in person).

57-307 Bagpipe Theory

Intermittent: 3 units
This course prepares students for 57-302, Bagpipe Construction. All aspects of Bagpipe Theory are covered, including time signatures, grand staff, musical rudiments, musical terms and definitions, and writing of simple tunes from memory.

57-329 Beginning Piano for Minors

Fall: 3 units
This is a small group lesson for music performance, music composition, music technology, and music theory minors who cannot pass the required beginning piano test.

57-330 Beginning Piano for Minors

Spring: 3 units
This is a small group lesson for music performance, music composition, music technology, and music theory minors who cannot pass the required beginning piano test.

57-331 Principles of Education

Fall: 9 units
This course introduces students to the art and science of being an educator. Content includes views of the academic and social structure of the school, physiological and amp; social characteristics of learners that influence instruction, widely recognized research on learning and amp; teaching, and appropriate and amp; effective class preparation and teaching strategies.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-332 Introduction to Conducting

Fall: 6 units
This course develops the basic skills needed to conduct instrumental ensembles or a small orchestra. It is primarily focused on conducting technique, body language and body coordination and communication. It also deals with learning and translating an instrumental or orchestral score into actual music. The goal is to achieve a clear and communicative technique upon which an artistic interpretation can be built. The student works periodically with a pianist or a small chamber ensemble.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-333 Band and Choral Arranging

Spring: 6 units
The main purpose of the course is to enable students to compose arrangements suitable for public performance for a cappella choir, instrumental chamber groups, and concert band. By the end of the course, students should achieve a satisfactory level of competence in regard to: 1. Effective writing through knowledge of instrumental and vocal performance techniques. 2. Writing homophonic, polyphonic, homorhythmic and monophonic textures for effective ensemble sound and variation. 3. Identifying and creating effective orchestration for instrumental and vocal ensembles. 4. Identifying expected music knowledge, performance ability, and attitudes of middle and high school music ensemble students.
Prerequisites: 57-150 or 57-153

57-334 Fundamentals of Marching Band

Fall: 3 units
A marching band, due to its visibility and high degree of student involvement, is an integral part of secondary school music programs. The well-schooled music education graduate must have knowledge of this unique form of music performance. This course, designed primarily for those seeking a career in teaching, will accommodate students with no experience and others who have participated in marching band. Among the many areas of concentration will be: philosophy, show charting, marching fundamentals and commands, logistical awareness, and budget formulation. Observation of and active assistance with Carnegie Mellon Kiltie Band will be part of the course content.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-336 Instrumental/Choral Conducting

Spring: 6 units
This course is a continuation of Introduction to Conducting. The course offers a more detailed conducting technique, adding those subjects related to choral conducting. This is followed by the study and the analysis of interpretation from the point of view of the conductor and ends stressing a set of important practical items, including the psychological attitude and the leadership a conductor must develop as well as the organization and achievement of a fruitful rehearsal technique. The students work periodically with a pianist, a soloist or a chamber ensemble on traditional works and on their own compositions in the case of composition majors.
Prerequisite: 57-332

57-337 Sound Recording

Fall and Spring: 6 units
Sound Recording is the first (and required) course in the sequence that includes Sound Editing and amp; Mastering and Multitrack Recording. Sound Recording centers around the Vlahakis Recording Studio in the College of Fine Arts: how the studio works, and how to record various types of music. The method of instruction is to learn by doing, and the goal is to achieve professional-sounding results. Equipment includes a complete 24-track Pro-Tools system, professionally designed control room that can accommodate up to 24 people, outboard preamps and other gear, and an interesting array of microphones. All recording is direct to hard disc. Grading is based on recording projects, class attendance, mastering studio hardware and software, and several quizzes. Work outside of class requires about 3 to 5 hours a week to complete projects and take-home quizzes.

57-338 Sound Editing and Mastering

Fall and Spring: 6 units
The raw recording is just the first step in the process of creating a professional finished audio product. "Editing" is the art of piecing together different takes to make one final 'good take.' "Mastering" is the art of polishing the 'good take' to perfection and #8212;balancing all the instruments and tracks, adding special effects, setting final levels. If 'recording' seems like an high-energy activity and #8212;involving engineers, musicians, producers and #8212;'editing and mastering' are the necessary counterparts and #8212;long tedious hours of solitary confinement honing the skills of the mastering engineer. Those taking this course are expected to have significant music skills: actively playing a musical instrument (or composition), and/or the ability to read a piano score at the least, and a full orchestra score from any recent century, including our own, at the most. Class attendance is essential; work outside of class is necessary.
Prerequisites: 57-651 or 57-337 or 57-341 or 57-342

57-339 Acting III

Fall: 6 units
This course will build upon the foundation laid in the first year, with a more concentrated look at scene work, an audition workshop that focuses on cold readings as well as monologues, and a character-development project that works to identify specific issues that inhibit freedom on stage. More in-depth work on songs and arias will lead into a musical scene project. The semester will close with a classical text project in which the students will work with verse.
Prerequisite: 57-241

Course Website: https://cmu.app.box.com/files/0/f/11681158556/1/f_106285564705 (https://cmu.app.box.com/files/0/f/11681158556/1/f_106285564705/)

57-340 Acting IV

Spring: 6 units
Continues 57-339 Acting III.
Prerequisite: 57-339

57-343 Music, Technology, and Culture

Intermittent: 9 units
Music has been a part of our individual and communal lives for 40,000 years. We developed the technology to record and playback music for about 140-years ago. In this seminar we will study the relationship of music, technology and culture from a variety of disciplinary approaches including science and technology studies, musicology and ethnomusicology, neuroscience, sound studies, critical race and ethnicity studies, political economy, cultural studies and media archeology. The course will focus on the impact mediating technologies like vinyl, cassette tapes, mp3s, film and television, the development of music journalism and of course live human performance have had on our social, political and personal interactions with music. We have built the course around case studies that illustrate the intersection of music, technology and culture such as audio analgesia devices, movie soundtracks, streaming services, the rise of internet "listicles" and other crucial moments in twentieth and twenty-first century musical culture. Students in this course will develop critical projects that cross technological, humanistic, and musical boundaries. We hope that students come away from this class with better a host of critical tools to better think about what music means to us and how mediating technologies redefine these meanings.

57-344 Experimental Sound Synthesis

Intermittent: 9 units
This is a course that will guide students into the world of experimental approaches to music and sound production, with particular emphasis in some of the key practices and concepts developed in the 20th and 21st centuries. We will examine a variety of ways in which sound works are made and perceived; understanding the historical perspectives and critical viewpoints of each approach through the application of hands-on practicum. The topics covered in the course are divided into three large areas: the art of sound, the use of technology in the production of sound works, and the creation of interdisciplinary sound installation. Students from different disciplines will work together to collaborate on the designing, prototyping and execution of a series of ambitious projects in response to the topics covered in class.

57-347 Electronic and Computer Music

Fall and Spring: 6 units
This course builds on the concepts learned in Introduction to Music Technology (57-101) and gives added knowledge in the areas of composition using digital and analog devices as well as various computer programs. Building computer models of both analog and digital synthesizers as well as drum machines, loop players and various other sound processing effects will be covered in detail. Students will be required to produce several projects throughout the course demonstrating their understanding of various concepts in electronic music. More emphasis is placed on the overall quality of the end musical product than in 57-101 in order to prepare students for music production in a professional setting.
Prerequisites: 57-101 or 57-171

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-350 Strauss Wind Serenade

Fall and Spring: 3 units
TBA

57-355 Secondary Guided Teaching

Spring: 3 units
This course enables students to apply instructional strategies in local secondary school music classes. School visits provide opportunities to work with band, choral, and amp; orchestral ensembles and general music classes. Seminar discussions with the cooperating teachers familiarize students with both school-wide and classroom management issues that affect teaching, learning, motivation, and the administration of music programs.

57-356 Elementary Guided Teaching

Fall: 3 units
This is the second level of field experience in the public schools. This course provides for observation and closely supervised teaching experiences with elementary age children in a school setting.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-358 Introduction to Electronic Music

Intermittent: 9 units
This course will allow students to produce original works of electronic music composition in response to strategic listening assignments presented within their historical context. Students will learn critical listening and analytical skills, and be assessed on their electronic music production as well as on their ability to articulate context and structure. This course is for undergraduate music students. Other students may register for it with the permission of the instructor.

57-359 Audiovisual Composition

Intermittent: 9 units
TBA
Prerequisite: 57-358

57-360 Brass Methods

Fall: 3 units
This music education course develops basic brass playing and teaching techniques for beginning and intermediate instrument classes. The course includes training in beginning band program design, aural and amp; visual diagnosis of individual and ensemble playing problems, and methods of accelerating music reading independence in young players. The course requires two off-campus field teaching experiences in local schools. Each field teaching experience will require about 3 hours to complete and #8212; students should allow enough time in their schedules to complete this requirement.

Course Website: https://cmu.app.box.com/files/1/f/11681158556/1/f_106285571873 (https://cmu.app.box.com/files/1/f/11681158556/1/f_106285571873/)

57-361 Percussion Methods

Fall: 3 units
This class gives the non-percussion major a background in the fundamentals of teaching percussion. The main focus of the course is snare drum. The students spend most of their time learning the basic concepts of beginning snare drum so they will be prepared to teach beginning students of any grade level. Much time is devoted to proper stance, grip, and stroke in order to insure a good foundation for a beginning student. Also covered are the various mallet instruments, timpani, and all small hand percussion. Students will learn about purchasing proper equipment for the various levels of learning in common school programs.

57-362 Woodwind Methods

Spring: 3 units
This music education course develops basic woodwind playing and teaching techniques for beginning and intermediate instrument classes. The course includes training in beginning band program design, aural and amp; visual diagnosis of individual and ensemble playing problems, and methods of accelerating music reading independence in young players. The course requires two off-campus field teaching experiences in local schools. Each field teaching experience will require about 3 hours to complete and #8212; students should allow enough time in their schedules to complete this requirement.

57-363 String Methods

Spring: 3 units
String Methods prepares music educators for work in the public schools. A major portion of class time will be applied to violin and cello techniques. Upon completion of the course, the student will be expected to demonstrate the technical skills of a second year beginning string student. Students will also be introduced to various method books, string supplies, and repairs.

57-364 Conducting Practicum

Fall and Spring: 3 units
This course provides applied conducting experience for the conducting minor.

57-370 Stage Direction

Spring: 3 units
This course provides an internship working with a middle or high school music theater production. Students may participate in coaching, direction, and choreography. In addition, they keep a journal of their experience and submit a final paper describing what they have learned from working with the teachers or professional directors who were responsible for the production. It is suggested that this course be taken during the spring semester when most music theater productions are scheduled.

57-374 Music in the Urban School

Spring: 9 units
This course will involve workshops with nationally known instructors in eurhythmics, world drumming, contemporary popular music, and classroom management. The course will require attendance at workshops, classroom observations and closely supervised teaching experiences, including up to 12 hours of practicum visitation to be fulfilled scheduled by the Instructor. This course fulfills the Community Engagement requirement in the Master's of Music degree program. Schools involved are all inner city schools with a poverty level of 75% or above. This course is offered as the result of a grant received from the Federal Department of Education by the School of Music, the Pittsburgh Public Schools, and the Wilkinsburg School District.

57-375 Music in the Elementary School

Fall: 6 units
This course is designed to provide a philosophical background for teaching music in the elementary school and to provide a variety of pedagogical techniques, which are essential when teaching music from Preschool through Grade 6.
Prerequisite: 57-331 Min. grade C

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-376 Music in the Secondary School

Spring: 6 units
This course covers a variety of topics related to the development and the management music programs in secondary schools. Emphasis is placed on the leadership, classroom management, general music and amp; performance course content, and routine administrative planning.
Prerequisite: 57-375 Min. grade C

57-377 Psychology of Music

Intermittent: 9 units
Music cognition is an interdisciplinary approach to understanding the mental processes that support musical behaviors, including perception, comprehension, memory, attention, and performance. Like language, music is a uniquely human capacity that arguably played a central role in the origins of human cognition. This course is a survey of current approaches to and theories about the perception and cognition of music. Topics covered include psychoacoustics; the cognitive neuroscience of music; relationships between music and language; the nature of musical knowledge; and debates about aesthetics, evolutionary psychology, and musical universals. At the end of this course a student should be able to identify key theories and hypotheses in music cognition as they relate to memory, emotion, physiology, neurology, acoustics, language, and evolution. They will be able to comparatively evaluate hypotheses and place them in an intellectual context. These objectives will be achieved though critical reading, discussions, and written exercises. There are no prerequisites for this course. It will be helpful for you to know some basic elements of music theory (such as the names for chords, Roman numerals, and so on), but some extra help will be available to cover these topics. Some notational basics will be covered in the first lecture.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-378 Introduction to Music Cognition Research

Intermittent: 9 units
This course explores the roles of cognitive processes in the experience of music with a focus on carrying out a collaborative laboratory project in order to understand first-hand the challenges of the experimental study of music. In readings, lectures, discussions, and demonstrations we will become acquainted with the relevant psychological theories of perception, memory and learning, and review and critically analyze selected experimental findings on the psychology of music. We will examine the use of psychological principles (e.g. Gestalt laws of perception, limitations on working memory, categorical perception, chunking, schemas, modularity) to explain musical phenomena. The emphasis will be on applying an experimental approach to music perception and cognition, but we will also consider ongoing debates about larger issues (such as musics adaptive value to the human species, and the determinants of musical taste). Prerequisite: either Harmony 1 or Intro to Cognitive Psychology.
Prerequisites: 57-149 or 57-152

57-381 Collaborative Piano I

Fall and Spring
These are a series of courses which allow the student the opportunity to accumulate experience in a professional setting with students and faculty. The pianist will be assigned to a voice studio(s) and play for students and their professional mentors, supervised by a Collaborative Piano faculty member. Assignments may include playing voice juries. This course is open to Music Majors and Non-Music Majors, based upon a mandatory audition prior to approval.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-382 Collaborative Piano II

Fall and Spring
These are a series of courses which allow the student the opportunity to accumulate experience in a professional setting with students and faculty. The pianist will be assigned to a voice studio(s) and play for students and their professional mentors, supervised by a Collaborative Piano faculty member. Assignments may include playing voice juries. This course is open to Music Majors and Non-Music Majors, based upon a mandatory audition prior to approval.
Prerequisite: 57-381

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-383 Collaborative Piano III

Fall and Spring
These are a series of courses which allow the student the opportunity to accumulate experience in a professional setting with students and faculty. The pianist will be assigned to a voice studio(s) and play for students and their professional mentors, supervised by a Collaborative Piano faculty member. Assignments may include playing voice juries. This course is open to Music Majors and Non-Music Majors, based upon a mandatory audition prior to approval.
Prerequisite: 57-382

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-384 Collaborative Piano IV

Fall and Spring
These are a series of courses which allow the student the opportunity to accumulate experience in a professional setting with students and faculty. The pianist will be assigned to a voice studio(s) and play for students and their professional mentors, supervised by a Collaborative Piano faculty member. Assignments may include playing voice juries. This course is open to Music Majors and Non-Music Majors, based upon a mandatory audition prior to approval.
Prerequisite: 57-383

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-385 Collaborative Piano V

Fall and Spring
These are a series of courses which allow the student the opportunity to accumulate experience in a professional setting with students and faculty. The pianist will be assigned to a voice studio(s) and play for students and their professional mentors, supervised by a Collaborative Piano faculty member. Assignments may include playing voice juries. This course is open to Music Majors and Non-Music Majors, based upon a mandatory audition prior to approval.
Prerequisite: 57-384

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-386 Collaborative Piano VI

Fall and Spring
These are a series of courses which allow the student the opportunity to accumulate experience in a professional setting with students and faculty. The pianist will be assigned to a voice studio(s) and play for students and their professional mentors, supervised by a Collaborative Piano faculty member. Assignments may include playing voice juries. This course is open to Music Majors and Non-Music Majors, based upon a mandatory audition prior to approval.
Prerequisite: 57-385

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-391 Keyboard Studies (Music Ed)

Fall and Spring: 3 units
This course develops piano skills necessary for work in the elementary and secondary schools. Special emphasis is placed on transposition, score reading, harmonization and sight-reading. This course is required for all music education majors.
Prerequisite: 57-191

57-392 Keyboard Studies (Music Ed)

Fall and Spring: 3 units
Continues 57-391 Keyboard Studies V. This course is required for all music education majors.
Prerequisite: 57-391

57-399 Music-Cinema-Culture

Intermittent: 9 units
The first 100 years of the 20th Century's only original art form, whose advent has brought about tremendous social and cultural changes. Students view selected films, learning first the basics of film theory, cinema's working structures and the function of music. Ultimately, they are able to analyze, in the form of a written essay, the function and value of the music in a particular film and the impact such music has had on society.

57-403 Yoga for Musicians

Fall and Spring: 3 units
TBA

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-404 String Quartet: A Social History

Intermittent: 9 units
The string quartet is at once a medium and a genre, even a form which for more than two hundred years has had a special, unparalleled place in Western music. This course examines the development of the string quartet - from its function as an intimate and conversational social setting for amateurs, to its role as a secret repository of composers' most daring thoughts. The string quartet repertoire under discussion spans the first attempts at string quartet writing in the 17th Century, to serialism and microtonal disintegration in the 1960's, to contemporary Pop-Rock fusion experiments. This course also deals with the social and personal histories of four individuals who freed themselves from hegemonic orchestral rules in favor of an instrumental democratic microcosm.

57-405 Concerto: Virtuosity and Contrast

Intermittent: 9 units
The Concerto, one of the most popular forms of music, is also a dramatic form, a drama of contrast between the strength of one body of sound and another (volume), between one type of sound and another (tonal distinction), between the individual and the masses, and finally, between the "Solo" virtuoso and the less gifted "Tutti" players. The goal of this course is to examine the greatest concerti written for all instruments; from Vivaldi's "Concerto for Two Mandolins" to John Adams's "Grand Pianola Music," and much more, while dealing with the social and personal histories of unforgettable virtuosi and the concerti that became their "Battle Horses." The program analyzes great concerti performed by the world's greatest soloists and orchestras.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-408 Form and Analysis

Spring: 6 units
This course provides a working understanding of all styles and genres of Western classical and contemporary repertoire. Students will explore various aspects of the compositional process, from basic organizational structures to the details of individual musical phrases. They will learn to see and to hear the most important compositional features of a piece of music and will develop a deeper understanding of the music they perform, conduct, and compose.
Prerequisites: 57-150 or 57-153

57-409 Puccini's Operas

Intermittent: 9 units
Standing between the 19th and 20th Centuries, Puccini witnessed extraordinary socio-political and cultural shifts sweeping across Europe. His operas reflect such changes through their gradual stylistic adherence to modernity. From theatrical and literary plots to complex relationships with poets, publishers, impresarios, singers, conductors, and political censors, Puccini's operas offer excellent grounds for interdisciplinary dialogue and cultural analysis.

57-411 Musical Theatre on Stage and Screen

Intermittent: 9 units
Defining what musical theater "is" is no easy task. The genre/form/phenomenon as we know it today represents an evolution of embodied practices and interdisciplinary creativity spanning cultures, geographies, traditions, media, and time. Similarly, the history of musical theateror, more appropriately, the histories of musical theatershould not be reduced to simple narratives or linear chronologies. Following this idea, this course offers a topical exploration of musicals on stage and screen, focusing on historical developments, production practices, and artistic agency from the mid-nineteenth century to the present. We will not offer a conventional "survey" of musicals starting from an arbitrary point "way back when" and ending with the state of things in 2022. Like the "concept musicals" of the mid-twentieth century, a non-linear structure allows us to consider broader connections across our subject(s). In addition to repertoire case studies, we will explore the historiography of musical theater; the process of developing musicals from page to stage; the function and labor of performers, administrators, stage directors, stage designers, and technical personnel in making musicals happen; musicals in various media; musicals in the time of the coronavirus pandemic; and concerns of social justice in reviving established works and producing new works. Assignments will include short analysis presentations and written responses. There is no performance component with this course.

57-412 The Operas of Richard Strauss

Intermittent: 9 units
Across a lifetime that spanned the nineteenth and twentieth centuries, Richard Strauss blazed a trail as a composer for the dramatic stage that was aesthetically eclectic, commercially successful, and critically divisive. His operas were "modernist" creations that presented musical, thematic, dramaturgical, and production challenges to the artists and audiences of his time. They still test the ingenuity of those who approach them today worldwide. This course offers students a survey of all fifteen of Strauss's completed operas as both musical and theatrical texts, working through at least one example per week. The emphasis on the composer's entire oeuvre corrects the familiar neglect of the middle and late works and views them all through a range of aesthetic and critical lenses. Though the primary emphasis of the course is musicological in nature and not musical theory, we will still examine Strauss's evolving stylistic approaches to form, harmony, orchestration, and vocal writing. Listening to complete recordings and viewing streaming productions will be important requirements. Assignments will include response papers, two short presentations presented in small groups, a take-home midterm exam, and a final exam.

57-417 Major Vocal Performance Ensemble

Fall and Spring: 6 units
There are two choral ensembles. Concert Choir is a select ensemble of approximately 40 voices of superior vocal/musical talent and experience in the choral idiom. Performance requirements are more stringent than those of the Repertory Chorus. Repertory Chorus is an ensemble of undetermined size. Emphasis is placed on vocal technique and development, musical skills in the rehearsal with minimum performance requirements. Audition required.

57-418 Major Instrumental Ensemble

Fall and Spring: 6 units
There are two instrumental ensembles: Orchestra and Wind Ensemble. Rotating seating plans, within and between ensembles, will prevail at the discretion of the Director of Orchestral Studies and the Director of the Wind Ensemble. The instrumental faculty will be consulted. All music majors who are required to enroll in an instrumental ensemble must audition for placement and enroll in Major Instrumental Ensemble. Audition required.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-420 JIVE - CMU Jazz Choir

Fall and Spring: 3 units
A highly selective group of mixed voices who perform contemporary jazz and pop vocal arrangements. Open to all CMU students. Previous registration or a successful audition for Jazz Vocal Ensemble will meet the prerequisite requirement. Contact the director, Betsy Lawrence and lt;blawrenc@andrew.cmu.edu and gt;, to schedule an audition.
Prerequisite: 57-420

57-421 Exploded Ensemble

Fall and Spring: 6 units
Exploded Ensemble is a group dedicated to the performance of music that pushes the boundaries of traditional performance and composition. The ensemble has a strong emphasis on electro-acoustic performance technique, experimental approaches to staging and amplification, and visuals (live video, computer controlled lighting, wearable technology, etc.). The group will perform works by new/experimental/electro-acoustic composers and will create new arrangements of works for which scores may not currently exist - for example, music by rock bands, electronic musicians, and sound artists. The overall goal of the ensemble is to explode the idea of traditional concert music performance. In so doing we shall advance student skills in music performance, music appreciation, and to advance the very important conversation on the future of concert music. Students interested in this course who have not had the prerequisite should contact the instructors.

Course Website: https://courses.ideate.cmu.edu/57-421 (https://courses.ideate.cmu.edu/57-421/)

57-423 Repertoire Orchestra

Fall and Spring: 3 units
This course thoroughly acquaints participants with the standard works one would expect to encounter as part of a career as an orchestral player. Assigned repertoire will be read each class session. All students are eligible to register for this course by special permission. Students who are not placed in the Carnegie Mellon Philharmonic are given priority for registration.

57-424 Percussion Ensemble

Fall and Spring: 3 units
This ensemble is open to all percussion majors.

57-427 Advanced Seminar in Film Musicology

Intermittent: 9 units
This course has been designed primarily for advanced students wishing to apply to film scores analytical methodologies pertaining to historical musicology, cultural studies, and genetic criticism. The films screened and the music analyzed in this course follow at first the historical development of cinema. Then, the syllabus focuses on the film music of Ennio Morricone in honor of his 90th birthday and on final presentations of film soundtracks selected by the students. Prerequisites include some knowledge of music history, theory, practice, or the instructor's permission.

57-429 Beginning Piano for Children I

Fall and Spring: 6 units
This course is the first of two courses in a year-long internship in the piano teaching of young children, combining class and private instruction: a study of the basic teaching/learning process as applied to piano teaching, covering comprehensive step-by-step presentation in reading, rhythm, ear training, sight reading, technique, and musicianship. Under supervision, students will teach the weekly group class and private lessons. Weekly conferences will be held for learning the presentation of materials for class teaching, analyzing pedagogical problems, and developing communication skills with both young pupils and their parents.
Prerequisite: 57-273

57-433 Musical Theatre Literature and Repertoire

Intermittent: 3 units
If you enjoyed participating in your high school musicals, this class is for you! Learn and perform songs from the musical theater repertoire, beginning with operetta to present day contemporary pieces. PDFs and practice tracks will be provided. Class performances will be live with a pianist.

57-434 Musical Theatre Literature and Repertoire

Intermittent: 3 units
Continues 57-433 Musical Theatre Literature and Repertoire.
Prerequisite: 57-433

57-436 English/Contemporary Literature and Repertoire

Intermittent: 3 units
The course provides a bibliography of repertoire in the English language. Material will be limited to art songs and will be presented via individual student or group performances in class, and recorded performances. Research assignments will be required for selected anthologies or for works by specific composers. Repertoire will be examined according to vocal requirements, musical style, and programmatic function. The repertoire will consist primarily of works by British and American composers, but works by Russian and Spanish composers will also be included.

57-437 Literature and Repertoire

Fall and Spring
This course deals with literature and repertoire for instruments. There are multiple sections organized by instrument categories or specific instruments. Section D - Woodwind Literature and Repertoire, open to undergraduate and graduate woodwind students, focus on standard orchestral repertoire. Each session covers at least one symphony, overture, tone poem, or concerto accompaniment. Special consideration is given to orchestra audition material generally required for flute, oboe, clarinet, and bassoon. Students are encouraged to request repertoire they wish to cover. Non woodwind students and non-registered students may request to participate if there is particular interest in a class or classes. Following are examples of repertoire from 2023-2024 classes: Brahms - Symphonies 2 and amp; 3; Academic Festival Overture Berlioz - Roman Carnival Overture Strauss - Don Juan Rimsky-Korsakov - Scheherezade Mozart - Marriage of Figaro Overture Tchaikovsky - Romeo and Juliet Overture Fantasy Rossini - La Gazza Ladra and amp; Barber of Seville Overtures Stravinsky - Firebird Suite Ravel - Daphnis and Chloe Suite No. 2

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-438 Multitrack Recording

Fall and Spring: 9 units
This course builds upon the ideas learned in Sound Recording (57-337), but with an emphasis on close microphone techniques and popular music styles. Students will work in small groups and complete at least two recording projects. $10.00 materials fee.
Prerequisites: 57-341 or 57-342 or 57-651 or 57-337

57-441 Analysis of 19th Century Music

Intermittent: 9 units
This course will provide students with a variety of tools for the analysis of music from Schubert to Mahler and early Schoenberg. The primary emphases will be on small-scale (chord-to-chord) harmonic organization, on the larger-scale organization of tonal centers, and on form, but other issues will also be explored (e.g. rhythm and meter, text/music relations). The course will sample a wide range of repertoires, including solo piano music, orchestral music, and opera, and it will have a special emphasis on chamber music including the German Lied.

57-442 Analytical Techniques

Fall: 9 units
What is music analysis and why is it important? How do we talk about our experiences with music? If I can analyze music, will it help get a job? An analytical technique is a way to perceive or embody music with someone else: to find resonance or even difference without presenting one's perception as objective and universal. We use analytical technics all the time in explicit ways and implicit ways when we make and listen to music. In this course, we will study western analytical techniques in their application to western classical, jazz, popular, and non-western musics. When appropriate, we will discuss non-western techniques, but they will not be a focus. We will learn traditional analytic methodologies and explore philosophical and cultural relationships between value, culture, identity, and analysis. There will be weekly readings, listening, and analysis assignments. In the first seven weeks we will focus on the analysis of western classical tonal music. In the second half of the semester we will focus on transcription and improvisation in diverse musical contexts. Students will complete a project in each of these three areas. This course utilizes in-class discussion and performance by all participants. The goal of this course is to improve your ability to conceptualize and perform new music and to enhance your engagement with your current repertoire.
Prerequisite: 57-408

Course Website: https://cmu.app.box.com/files/0/f/11681158556/1/f_106285568801 (https://cmu.app.box.com/files/0/f/11681158556/1/f_106285568801/)

57-444 Principles of Counterpoint

Intermittent: 9 units
This course explores the development of Western music composed with multiple independent parts. The first half of the course traces the history of part-writing from medieval organum to the twenty-first century. Emphasis is given to study of pre-Baroque and twentieth-century music, and to the conceptual shifts that occurred moving in and out of the common-practice period. The second half of the course examines, across multiple musical styles, specific contrapuntal techniques such as imitation and ground bass forms. Assignments include both writing exercises and analysis, culminating in a term project on a topic selected by the student.
Prerequisites: 57-152 or 57-149

57-445 Counterpoint in 18th Century Composition

Intermittent: 6 units
In this course the student will study how to write two-part counterpoint within the harmonic framework of 18th-century instrumental music. The focus of study will be J.S. Bach's inventions, and writing will be directed towards composing several complete inventions in that style. Prerequisites: Harmony I and Harmony II or permission of the instructor. This course is designed for composers, theory minors, Bach lovers, keyboard majors, and anyone who wants to seriously sharpen their tonal writing skills.
Prerequisite: 57-408

57-446 Renaissance Counterpoint

Intermittent: 6 units
In this course the student will study how to write vocal counterpoint using the classic "species" approach, based on the style of Renaissance masters Palestrina, Lassus, and Victoria. The latter part of the course will extend the study to instrumental music of the 16th century, and explore the development of chromaticism in avant-garde composers of the time. Reading about and listening to Renaissance music and composers will be included as background context for the theory work. Daily writing exercises in the first part of the course will lead to a term project producing a performable piece of music by the end of the semester. This course is designed for composers (both for writing technique and college teaching preparation), theory minors, early music lovers, choral singers and conductors, church musicians, and anyone who wants to sharpen their writing skills. Prerequisite: Harmony I or permission of the instructor (demonstrated competence in reading treble and bass clef, and intervals).
Prerequisite: 57-408

57-447 Harp Pedagogy

Fall and Spring: 3 units
TBA

57-448 Brass Pedagogy

Fall: 3 units
In this course we introduce the "Art of Teaching". In this case, to teach, develop and encourage young brass players just starting an instrument or who are in their early stages of development. Concepts of basic brass pedagogy will involve the following topics: Music as Metaphor; Teaching young students; Listening; Developing a Concept of Sound; Posture; Breathing; Embouchure; Articulation: Single Tonguing, Multiple Tonguing; Mouthpiece playing; The Warm-up; Slurring; Intonation; The Upper Register; Endurance; Vibrato; Dental Braces; Orchestral Playing; Performance Preparation; Taking Auditions Brass students will leave CMU with a basic understanding of the pedagogical needs and requirements of beginning and inexperienced students, so that they may begin private teaching studio upon graduation.

57-449 Beginning Piano for Children II

Fall and Spring: 6 units
This course is the second of two courses in a year-long internship in the piano teaching of young children, combining class and private instruction: a study of the basic teaching/learning process as applied to piano teaching, covering comprehensive step-by-step presentation in reading, rhythm, ear training, sight reading, technique, and musicianship. Under supervision, students will teach the weekly group class and private lessons. Weekly conferences will be held for learning the presentation of materials for class teaching, analyzing pedagogical problems, and developing communication skills with both young pupils and their parents.
Prerequisite: 57-429

57-450 Audience Development

Intermittent: 6 units
TBA

57-451 The Citizen Artist

Intermittent: 6 units
This course celebrates the intersection of artistry and citizenship by engaging in conversation around social justice and exploring ways in which music can uplift our Pittsburgh community. We will collaborate with Autism Pittsburgh and the Lullaby Project to create artful musical experiences that engage families with autism and foster connection between parents and babies. Musicians, artists, and social advocates across campus are invited to participate.

57-452 Collaborative Project in Music Entrepreneurship: innovation in music & wellness

Intermittent: 6 units
The project for Fall 2024 is to develop a new performance modality at the intersection of music and wellness for CMU's new Highmark Wellness Center. Students will explore the effects of music on mental health in order to create musical experiences that appeal to new audiences and enhance well-being in the community. Students with skills in project management, social media, business, music technology, lighting design, and experience design are encouraged to join. Music performance is not required. A high level of personal initiative and professionalism is expected. Deliverables are: beta-version of innovative music and amp; wellness experience, documentation of the process, budget, and panel presentation to faculty.

57-454 The Freelance Musician

Intermittent: 6 units
This course will put you in touch with innovative artists, managers, web designers, career consultants, and other professionals who want to help you succeed. There is nothing theoretical about this course: you'll perform "real gigs for real clients" who will offer feedback on your professionalism. You'll build a website with expert support and gain clarity on how music fits into your higher purpose. The objective of this course is to make you "roadworthy" as a professional musician, equipping you with the tools, skills, and mindset that would make people want to work with you again and again. You can think of it in three stages: "building the car" (professional portfolio), "tuning the engine" (communication); and "mapping the route" (strategy) to put you on the road to success. No prior knowledge or experience is required to take this course. You have already spent thousands of hours practicing to become a fine musician. Turning your artistry into a livelihood requires an entirely different skillset, which can be jumpstarted (in only about 50 hours) so let's get going!

57-455 Shaping Time in Performance

Intermittent: 9 units
This course will look at basic questions that performers face: Which level of pulse do I want to feel as the main one? How can I shape a pulse expressively? Which measure in a phrase is felt as a main goal, especially when the phrase contains an unusual number of measures? How can multiple tempi be meaningfully related? Among many important formal arrival points, which are the most important? In addition to these questions, we will also look at recent work on ways in which 18th-century musicians may have understood meter very differently from most musicians today. These alternate perspectives open new possibilities for hearing and shaping the flow of musical time in baroque and classical music. These issues will be pursued from two directions. We will develop simple theoretical tools that can make score analysis a helpful input to the decisions that performers make about such questions. We will also examine audio and video recordings by famous artists to see both how they dealt with these issues and what new questions are raised. Week-to-week work will include reading, listening, and score analysis. Students will write term papers that either use one of the main perspectives developed in class (starting from scores or starting from recordings) or else combine the two. They will also give presentations about their projects to the class.

57-456 Marketing for Musicians

Intermittent: 6 units
What is your message? Who is your audience? How do you reach them? These are among the topics we'll explore in this course. Group projects and case studies help us identify the key aspects of one of the most important aspects of any music career. Being a great musician won't do you any good if no one knows you exist! By the end of the semester, students should be able to understand such concepts as branding, marketing, reach and advertising; identify audience segments and target messages to those segments; create compelling marketing materials, including bios, group and program descriptions, websites and flyers; work with teams to try out a variety of marketing strategies in real-world circumstances; learn to capitalize on social media and use it to effectively build and communicate to an audience; learn to write effective and powerful marketing copy (bios, sales pieces, etc.); examine competitors and market leaders to look for opportunities and best practices.

57-457 Mental training for peak performance

Intermittent: 6 units
Perform in Kresge Theatre regularly and gain tools for overcoming performance anxiety to own the stage and play your best. Everyone gets nervous, but it doesn't need to be debilitating. Learn how to calm your mind and turn nervous energy into mental focus. Guest faculty, PSO musicians, and visiting artists share their challenges and offer strategies for audition preparation, effective practicing, self-care, conflict resolution, and other mind-body topics.

57-458 Business of Music

Intermittent: 6 units
This class will teach you the fundamentals of how to survive in the music industry. A diverse set of speakers, hands-on projects tailored to your interests and needs and group activities will introduce you to the challenges you'll face during your career. How to manage your money, what you need to know about copyright, whom do you need on your side? We'll cover all of these and more!

Course Website: https://cmu.app.box.com/files/1/f/11681158556/1/f_106285572641 (https://cmu.app.box.com/files/1/f/11681158556/1/f_106285572641/)

57-459 Score Reading for Composition Majors and Conducting Minors

Spring: 6 units
This course is a practical, hands-on learning experience. Students learn by doing and observing other students. All work is done at the keyboard. It is for graduate collaborative piano majors, junior and senior composition majors, and junior and senior conducting minors with good keyboard skills who have completed Keyboard Studies or have otherwise satisfied the requirement. Other music majors with good keyboard skills who have completed Keyboard Studies or have otherwise satisfied the requirement can take this course with instructor permission.
Prerequisites: 57-194 or 57-192 or 57-191 or 57-193

57-461 Aural Analysis and Basic Improvisation

Intermittent: 9 units
Where are we now? Musicians often face analytical questions in performing situations. What scale degree is the trumpet playing? What chord are we playing now? What countermelody are the altos singing? What is the form, and where are we in it? The purpose of this course is to enhance students' abilities to answer these kinds of questions in real-time, real-world performance situations, apart from the score. The primary skills developed in the course will be hearing melodic scale degrees, hearing harmonies, memorizing short melodic fragments, identifying short harmonic idioms by ear, hearing two-voice contrapuntal music, and improvising over repeated chord progressions. A variety of conventional and unconventional games and exercises will be employed, involving notating, singing, and using the students' main instruments. We will also put these skills to use in doing larger-scale analysis by ear of longer passages, focusing especially on form, including entire movements. Improvisation comes into the course because perception and production are deeply intertwined; fun improvisation exercises, mostly using the idioms of popular music, will strengthen aural abilities much more than passive identification and dictation exercises could alone.
Prerequisite: 57-408

57-463 Consumer Driven Composition for Contemporary Media

Intermittent: 3 units
This course aims to augment each student's compositional skill set with technological skills and industry-specific knowledge that will provide them the flexibility and confidence to interface with consumers and more readily monetize their music. This course is intended to be part lecture to allow for quick and concise transfer of information, and part seminar to allow all class participants the ability to learn from each other as they pitch ideas, receive feedback, and evaluate the success of their peers' work. The course is for Sophomore, Junior, Senior, and Graduate Composition Majors. For undergraduate students, the only required prerequisite is 57-101 Introduction to Music Technology.

57-464 Music & Money

Intermittent: 6 units
This course is intended to develop in the student a broad knowledge of the music business, an entrepreneurial mindset applicable to it, and to encourage curiosity about future possibilities in the field. Students will examine the musical groups, ensembles, and institutions from the standpoint of economic, business and marketplace realities. Musical entities will be considered and studied not for their inherent artistic merit but as commodities affected by the same forces as any other consumable. Students will acquire a basic understanding of the forces - economic, financial, psychological, societal - that affect entities in the music field. They will also be called upon to think creatively and entrepreneurially about possible directions for existing musical entities. Students will become familiar with current methods of musical content creation, delivery platforms, advertising and marketing avenues, and revenue streams. Students will consider the history, economic structure, opportunities, and the challenges faced by each. Students will encounter and react to case studies taken from the music field about individuals and groups and the decision-making mechanisms at work in each, and the outcomes of the decisions taken by these individuals and groups.

57-465 Eurhythmics Applications for Performing and Teaching

Fall: 6 units
Rhythm is about time and timing. Dalcroze Eurhythmics is an exploration of the rhythm inside us. Experiencing rhythm through music and movement brings awareness and understanding of our own inner rhythm as well as rhythm in all the arts and beyond. For musicians, meaningingful rhythmic movement reinforces understanding of music concepts while focusing awareness on the physical demands of artistic performance. This approach to musical problem solving is applicable also to studio and classroom teaching.
Prerequisite: 57-164

57-467 Production: Crew

Fall: 3 units
Technical crew learning backstage operations for the fully staged productions presented by the Production: Performance class. Class participants serve as install, strike and run crew for the production.

Course Website: https://canvas.cmu.edu/courses/36963 (https://canvas.cmu.edu/courses/36963/)

57-468 Production: Crew

Spring: 3 units
Technical crew learning backstage operations for the fully staged productions presented by the 57-471 Production: Performance class. Class participants serve as install, strike and run crew for the production.

Course Website: https://canvas.cmu.edu/courses/36963 (https://canvas.cmu.edu/courses/36963/)

57-471 Production: Performance

Fall: 6 units
Preparation of an operatic or musical theatre production with a fully staged public performance of the production at the end of the class.
Prerequisites: 57-212 and 57-340

57-472 Production: Performance

Spring: 6 units
Preparation of an operatic or musical theatre production with a fully staged public performance of the production at the end of the class.
Prerequisites: 57-212 and 57-340

57-473 Production: Performance

Fall and Spring: 3 units
TBA

57-476 How Music Works: An Affective History

Intermittent: 6 units
This is an historical survey of (a) aesthetic theories about music and human agency and #8212;music's affects and effects, thus its significance and even its very existence and #8212;and of (b) actual utilizations of music. Theories range from Aristotle's catharsis to trauma theory and neuromusicology in our time. The applications range from the biblical David's therapeutic harp playing in the court of King Saul (11th C. BCE) to U.S. interrogators in Iraq (21st C. CE); from Vodun and exorcisms in other cultures to MUZAK in our own. In short, it's a chronological survey of what peoples have believed about music's powers and, consequently, how music has been used and abused. The dialectic between theory and applications is reflected in the assignments. This seminar is heavily focused on reading, as well as written and verbal discussion. There is also a long-term field project.

57-477 Music of the Spirit

Intermittent: 6 units
This guided listening course is a musical exploration of spirituality, a musicological and ethnomusicological survey organized around comparative religions. While the majority of repertoire will be from the Western Classical tradition, musics of a variety of cultures will be included. The music will be organized by particular religious traditions and by universal themes, such as community, death/afterlife, birth/new birth, martyrs/heroes, transcendence / immanence, meditation/contemplation/trance, etc. Most course materials, including streaming audio, are online, with one meeting per week in the classroom. Will include participatory introductions to numerous forms of chant. Requires oral and written reports.

57-478 Survey of Historical Recording

Intermittent: 6 units
The histories of music and technology have long been intertwined. Their symbiosis intensified with the harnessing of electricity in the third wave of the Industrial Revolution. This course will expose you to many of the best practitioners of music. But it will do so with an eye and #8212;an ear and #8212;towards the media by which we have known them. In short ... The music. The personalities. The media. This seminar is heavy on listening (guided playlists online via Canvas). Writing includes reviews and a researched feature article.

57-480 History of Black American Music

Fall and Spring: 6 units
Come and explore the rich musical heritage of Black America. This course will survey the music of Black America beginning with the African legacy and continuing through the music of the Twentieth Century. Class sessions will involve discussions, listening, viewing of films, and reports by students on topics of individual interest. Discussions will involve, historical, cultural and political perspective, as well as the music and composers themselves. Lecturing will be at a minimum. Innovative testing in quiz show format will be used. No prerequisites required. Open to all upper level undergraduate students.

57-485 History of the Symphony

Intermittent: 9 units
This course is a study of major symphonic works from 1750 to the modern period. For reasons we will examine, symphonic literature, and the symphony in particular, has long been considered Western art music's greatest monument to its history. Composers have agonized over its composition, conductors have devoted careers to it, and audiences have deeply and zealously expressed their admiration for it. We want to understand why this music is so revered and long-lasting. And we want to understand how the aesthetics of these works have been shaped by their historical, socio-cultural contexts, and how their meaning and value continue to change. Over the course of the term, we will analyze some of the great examples of this genre. We will place them in their historical, socio-cultural contexts with primary sources and insightful academic scholarship. Your critical listening, reading, and thinking skills will be expanded as we delve into almost three centuries of music and writings.

57-487 Advanced Solfege III

Fall: 3 units
Covers the same concepts as Solfege IV in more challenging material, from Bach chorales in open score to excerpts by Bartok, Honegger, Stockhausen, or Boulez. Dictations are three-part contrapuntal and difficult harmonic three and four parts.
Prerequisite: 57-186

Course Website: https://cmu.app.box.com/files/0/f/11681158556/1/f_106285567265 (https://cmu.app.box.com/files/0/f/11681158556/1/f_106285567265/)

57-488 Advanced Solfege IV

Spring: 3 units
Continues 57-487 Advanced Solfege III.
Prerequisite: 57-487

57-489 Practice Teaching (Elementary)

Fall and Spring
Experience in working with elementary students in a public school setting. The teaching is supervised by an experienced public school teacher and members of the CMU music education faculty.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-490 Practice Teaching (Secondary)

Fall and Spring
Experience in working with secondary students in a public school setting. The teaching is supervised by an experienced public school teacher and members of the CMU music education faculty. Students may choose a vocal or instrumental emphasis in the secondary placement.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-491 Solfege for Conductors I

Intermittent: 3 units
TBA
Prerequisites: 57-184 or 57-488

57-492 Solfege for Conductors II

Intermittent: 3 units
TBA
Prerequisites: 57-491 or 57-488

57-496 BXA Studio (1st semester)

Fall and Spring: 9 units
TBA

57-497 BXA Studio (2nd semester)

Fall and Spring: 9 units
TBA
Prerequisite: 57-496

57-498 BXA Studio (3rd semester)

Fall and Spring: 9 units
TBA
Prerequisite: 57-497

57-499 BXA Studio (4th semester)

Fall and Spring: 9 units
TBA
Prerequisite: 57-498

57-500 Major Studio (Voice)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

57-501 Major Studio (Piano)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-502 Major Studio (Organ)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

57-503 Major Studio (Harp)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-505 Major Studio (Violin)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

57-506 Major Studio (Viola)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

57-507 Major Studio (Cello)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

57-508 Major Studio (Double Bass)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

57-509 Major Studio (Guitar)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: http://www.music.cmu.edu/pages/insidemusic-coursesyllabi (http://www.music.cmu.edu/pages/insidemusic-coursesyllabi/)

57-510 Major Studio (Flute)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-511 Major Studio (Oboe)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-512 Major Studio (Clarinet)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-513 Major Studio (Bassoon)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

57-514 Major Studio (Saxophone)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-515 Major Studio (Horn)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-516 Major Studio (Trumpet)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-517 Major Studio (Trombone)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

57-518 Major Studio (Euphonium/Baritone)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-519 Major Studio (Tuba)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-520 Major Studio (Percussion)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

57-521 Major Studio (Composition)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-522 Major Studio (Bagpipe)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-523 Major Studio (Electronic Music)

Fall and Spring: 9 units
A one hour private lesson per week for all music majors.

57-557 Vocal Methods

Spring: 3 units
This course enables each student to develop a pleasant, healthy, and musically expressive voice and effective vocal pedagogy.

57-559 Music and Triads: Before/Beyond Roman Numerals in Western Music

Intermittent: 9 units
In many western traditions, the triad is a foundational element for musical construction. Though the ingredient is consistent across many styles, how it is used changes according to time, place, and even for the individual piece. This course is a deep dive into the ways in which triads are used in a variety of western traditions. We will track common practices and notable manipulations across diatonic music, modal, non- and poly- and pan-tonal repertories, and use different methods of notation, annotation, and engagement to better understand how the triad is used in music. Through listening, annotation, performance, and discussion, students will develop methods to identify triad and triad-expanding material, and to build usable analytical practices that are sensitive to the unique sonic footprints of specific musical styles. They will hone skills to communicate their findings, and transfer their interpretation into performance and creative practice. Students will be assessed through regular listening, analytical, and creative assignments, as well as in-class discussion and a final project or paper.

57-560 Electronic Music Seminar

Fall and Spring: 3 units
tba

57-570 Music and Technology Seminar

Fall and Spring: 1 unit
The Music and Technology Seminar is a weekly meeting to discuss topics in the areas of computer music, electronic music, musical acoustics, music perception, music technology, music information retrieval, music interfaces, music systems and software, and music theory. Presentations on these various topics are made by graduate students and faculty. The seminar is open to the University and broader community, but students should only enroll if the seminar is part of their degree requirements.

57-571 Music and Technology Project

Fall and Spring: 12 units
TBA

57-572 Music and Technology Project

Fall and Spring: 12 units
TBA

57-587 Sophomore Review

Fall and Spring: 1 unit
TBA

57-588 Junior Recital Voice

Fall: 1 unit
tba

57-589 Senior Recital Voice

Fall: 1 unit
tba

57-590 Internship

All Semesters
TBA

57-591 Dalcroze Pedagogy/Practice Teaching

Fall: 3 units
This course gives hands-on experience in applying Dalcroze principles in teaching situations. It is designed for students interested in learning about the teaching of Eurhythmics, general Music Education, and for those considering the Dalcroze Certificate. The class will meet in a three week rotation of two Thursday evenings followed by a Saturday morning with the Preparatory School children's classes.

57-593 Vocal Coaching

Fall and Spring: 1 unit
TBA

57-595 Senior Electronic Music Project

Fall and Spring: 1 unit
TBA

57-597 Senior Composition Project

Fall and Spring: 1 unit
A composition for orchestra required of all senior composition majors.

57-598 Junior Recital

Fall and Spring: 1 unit
A half recital required of all junior performance majors.

57-599 Senior Recital

Fall and Spring: 1 unit
A full recital required of all senior performance majors.

57-603 Practice Teaching (Elementary)

Fall and Spring
Experience in working with elementary students in a public school setting. The teaching is supervised by an experienced public school teacher and members of the CMU music education faculty.
Prerequisites: 57-355 and 57-393

57-604 Practice Teaching (Secondary)

Fall and Spring
Experience in working with secondary students in a public school setting. The teaching is supervised by an experienced public school teacher and members of the CMU music education faculty. Students may choose a vocal or instrumental emphasis in the secondary placement.
Prerequisites: 57-355 and 57-393

57-610 Internship

Fall and Spring
A student can receive credit for an unpaid internship in a music related field. The amount of credit is determined by the number of internship hours.

57-611 Independent Study in History

Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-612 Independent Study in Theory

Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-613 Independent Study in Research

Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-614 Independent Study in Performance

Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-615 Independent Study in Literature and Repertoire

Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-616 Independent Study in Sound Studies

Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-617 Independent Study in Electronic and Experimental Music

Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-618 Independent Study in Conducting

Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-619 Independent Study in Opera

Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-620 Independent Study in Solfege

Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-621 Independent Study in Eurhythmics

Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-622 Independent Study in Sound Recording Production

Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-623 Independent Study in Studio Recording Project

Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-624 Independent Study in Special Music Project

Fall and Spring
Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-627 Independent Study in Supervised Teaching

Fall and Spring
TBA

57-643 Diverse Populations in Inclusive Settings

Fall: 9 units
tba

57-670 Chamber Music: Brass

Fall and Spring: 3 units
Provides an opportunity for students to play in small ensembles, advised by faculty coaches. The performers will develop effective rehearsal techniques, explore chamber music repertoire, deal with issues of intonation and balance, and arrive at interpretive conclusions that are stylistically sound, yet individualistic and creative. A performance is required each semester.

57-671 Chamber Music: String Quartet

Fall and Spring: 3 units
Provides an opportunity for students to play in small ensembles, advised by faculty coaches. The performers will develop effective rehearsal techniques, explore chamber music repertoire, deal with issues of intonation and balance, and arrive at interpretive conclusions that are stylistically sound, yet individualistic and creative. A performance is required each semester.

57-672 Chamber Music: Woodwind and Mixed

Fall: 3 units
Provides an opportunity for students to play in small ensembles, advised by faculty coaches. The performers will develop effective rehearsal techniques, explore chamber music repertoire, deal with issues of intonation and balance, and arrive at interpretive conclusions that are stylistically sound, yet individualistic and creative. A performance is required each semester.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

57-675 Chamber Ensemble

Fall and Spring: 3 units
Provides an opportunity for students to play in small ensembles, advised by faculty coaches. The performers will develop effective rehearsal techniques, explore chamber music repertoire, deal with issues of intonation and balance, and arrive at interpretive conclusions that are stylistically sound, yet individualistic and creative. Low Brass Ensemble: The low brass ensemble pushes the boundaries of what is "supposed" to be played by an ensemble of this type. Players will be involved in the programming, arranging and planning pf performances and will learn valuable musical, creative, promotional and organizational skills.

57-874 Music in the Urban School

Spring: 9 units
This course will involve workshops with nationally known instructors in eurhythmics, world drumming, contemporary popular music, and classroom management. The course will require attendance at workshops, classroom observations and closely supervised teaching experiences, including up to 12 hours of practicum visitation to be fulfilled scheduled by the Instructor. This course fulfills the Community Engagement requirement in the Master's of Music degree program. Schools involved are all inner city schools with a poverty level of 75% or above. This course is offered as the result of a grant received from the Federal Department of Education by the School of Music, the Pittsburgh Public Schools, and the Wilkinsburg School District.
Prerequisite: 57-831

57-911 Music Since 1945

Intermittent: 9 units
A survey of Western art music from WWII to the present, with a focus on compositional techniques, influential trends, and experimental approaches. This course will address total serialism, aleatory music, the rise of technology, minimalism, and soundscape composition, among others. Students will engage with primary sources, close listening, multi-media resources, and secondary sources, and demonstrate competency through varied assessments, including in-class performance activities and presentations.

Course Website: https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2 (https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/)

The Marianna Brown Dietrich College of Humanities and Social Sciences

Richard Scheines, Bess Family Dean

Sharon Carver, Associate Dean for Educational Affairs

Joseph E. Devine, Associate Dean for Undergraduate Studies

Kelli Maxwell, Associate Dean for Student Success
www.cmu.edu/dietrich/ (http://www.cmu.edu/dietrich/)

The Dietrich College of Humanities and Social Sciences consists of undergraduate programs in English, History, Information Systems, Languages, Cultures, and Applied Linguistics, Philosophy, Psychology, Social and Decision Sciences, and Statistics & Data Science, as well as those offered by the Carnegie Mellon Institute for Strategy and Technology. Dietrich College also offers a student-defined major option, numerous interdepartmental majors, the intercollege Bachelor of Humanities and Arts program, and honors and pre-professional programs.

The college embodies one of the most varied groups of students, faculty, staff and alumni in the Carnegie Mellon University community, all united by a common goal: confronting and solving society's most complex problems. We learn through experience, and we work without silos or walls. Our students and faculty work across traditional boundaries, collaborating with other disciplines to pursue the thrill of discovery. Dietrich College is a place to explore different points of view. And a place to do work that matters.

At Dietrich College, we approach education differently. We mash up the traditional liberal arts with analytical and computational approaches. Beginning in their first year, our undergraduates confront real-world problems like democracy and data, racism or environmental justice through Grand Challenge Seminars (https://www.cmu.edu/dietrich/students/undergraduate/programs/grand-challenge/) that are co-taught by faculty from disciplines across the college and university. In addition, students are required to take General Education (https://www.cmu.edu/dietrich/gened/) courses tied to specific learning goals. These courses help students to acquire and apply new knowledge and skills that are essential to their careers, citizenship and life. In addition to the required courses, students' schedules also allow for broad exploration of our majors and minors (https://cms-staging.andrew.cmu.edu/dietrich-2/academics/degrees-majors-minors/). Experiential learning programs (https://www.cmu.edu/dietrich/students/prospective/undergraduate/experiential-learning.html) – like internships, undergraduate research, study abroad and community service – enhance our students' undergraduate education.

Dietrich College students develop deep disciplinary knowledge — but that's just the beginning. Students learn how to work on teams involving many disciplines. The knowledge landscape changes rapidly, and what students learn today may be outdated tomorrow. At Dietrich, students "learn how to learn," discovering how to communicate, think and understand the world in ways that will benefit them for the rest of their lives.

Dietrich College alumni report that the skills they learned while in college have helped them land opportunities in a highly competitive job market. Just as importantly, those skills helped graduates follow their passion and succeed in new endeavors outside a more traditional career path. Among the 90% of the Dietrich College class of 2022 (https://www.cmu.edu/career/outcomes/post-grad-dashboard.html) reporting, 94% found employment, entered graduate school or pursued other interests, like volunteering or military service.

Degree and Program Options

Dietrich College offers a wide range of majors and minors. In addition, there are a number of special programs which add breadth and enhance a student's overall experience.

Dietrich College Majors

Department	Name of Major (Degree Options)
Carnegie Mellon Institute for Strategy and Technology	**International Relations and Political Science (B.S.)**
Carnegie Mellon Institute for Strategy and Technology	**Political Science, Security, and Technology (B.S.)**
English	**Literature and Culture (B.A.)**
English	**Creative Writing (B.A.)**
English	**Film and Visual Media (B.A.)**
English	**Professional Writing (B.A.)**
English	**Technical Writing and Communication (B.S.)**
History	**Global Studies (B.A.)**
History	**Social and Political History (B.A./B.S.)**
Interdepartmental (1)	**Economics and Politics (B.S.)**
Interdepartmental (2)	**Economics and Statistics (B.S.)**
Interdepartmental (3)	**Environmental and Sustainability Studies (additional major only)**
Interdepartmental (4)	**Ethics, History, and Public Policy (B.A./B.S.)**
Interdepartmental	**Health Humanities (additional major only)**
Interdepartmental	**Information Systems (B.S.) (by admission)**
Interdepartmental (5)	**Linguistics (B.A.)**
Interdepartmental (6)	**Neuroscience (B.S.)**
Interdepartmental (7)	**Psychology and Biological Sciences (B.S.)**
Interdepartmental (8)	**Statistics and Machine Learning (B.S.)**
Interdepartmental (9)	**Statistics and Mathematical Sciences**
Interdepartmental (10)	**Statistics and Neuroscience**
Interdepartmental	**Student-Defined (B.A./B.S.) (by admission)**
Languages, Cultures, and Applied Linguistics	**Chinese Studies (B.A.)**
Languages, Cultures, and Applied Linguistics	**French and Francophone Studies (B.A.)**
Languages, Cultures, and Applied Linguistics	**German Studies (B.A.)**
Languages, Cultures, and Applied Linguistics	**Hispanic Studies (B.A.)**
Languages, Cultures, and Applied Linguistics	**Japanese Studies (B.A.)**
Languages, Cultures, and Applied Linguistics	**Russian Studies (B.A.)**
Philosophy	**Logic and Computation (B.S.)**
Philosophy	**Philosophy (B.A.)**
Psychology	**Cognitive Science (B.S.)**
Psychology	**Psychology (B.A./B.S.)**
Social and Decision Sciences	**Behavioral Economics (B.S.)**
Social and Decision Sciences	**Decision Science (B.S.)**
Social and Decision Sciences	**Policy and Management (B.S.)**
Statistics and Data Science	**Statistics (B.S.)**

Notes:

[1] Offered jointly by the Undergraduate Economics Program and the Carnegie Mellon Institute for Strategy and Technology
[2] Offered jointly by the Undergraduate Economics Program and the Department of Statistics and Data Science
[3] Offered jointly by the Dietrich College of Humanities and Social Sciences and the Mellon College of Science
[4] Offered jointly by the Departments of History and Philosophy
[5] Offered jointly by the Departments of English, Languages, Cultures, and Applied Linguistics and Philosophy
[6] Offered jointly by the Department of Biological Sciences and the Center

Additional Majors

Dietrich College students may pursue additional majors and/or minors in the college, as well as in other Carnegie Mellon colleges. An additional major refers to the completion of the requirements for a second major while also completing the requirements for the primary major and degree.

Most Dietrich College majors are also available as additional majors; two (Environmental and Sustainability Studies and Health Humanities) are available **only** as additional majors. Students from outside Dietrich College can pursue additional majors offered by the college, and would be required to complete only those courses in the college's general education program that are prerequisites to courses required for the Dietrich College major in question.

Minors

Minors are like majors in that they consist of coherent programs of study in a department, or across departments. Minors differ from majors in the number of the courses required and in the breadth and depth of the curriculum in the minor's area(s) of study. Dietrich College students can also pursue minors offered and made available by other Carnegie Mellon colleges and departments.

There are two types of minors in Dietrich College: departmental minors, which are housed in a single Dietrich College academic department; and interdepartmental minors, which are sponsored by more than one academic department and administered through the faculty advisor's academic department. The college's minors are available to students from all colleges in the university.

Department	Name of Minor
English	**Creative Writing**
English	**Humanities Analytics**
English	**Film and Visual Media**
English	**Professional Writing**
English	**Technical Writing**
History	**Anthropology**
History	**Social and Political History**
Carnegie Mellon Institute for Strategy and Technology	**American Politics and Law**
Carnegie Mellon Institute for Strategy and Technology	**Cybersecurity and International Conflict**
Carnegie Mellon Institute for Strategy and Technology	**International Relations and Political Science**
Carnegie Mellon Institute for Strategy and Technology	**Military Strategy and International Relations**
Carnegie Mellon Institute for Strategy and Technology	**Politics and Public Policy**
Carnegie Mellon Institute for Strategy and Technology	**Political Science, Security, and Technology**
Interdepartmental	**African and African American Studies**
Interdepartmental	**Environmental and Sustainability Studies**
Interdepartmental	**Gender Studies**
Interdepartmental	**Health Care Policy and Management**
Interdepartmental	**Linguistics**
Interdepartmental	**Neural Computation**
Interdepartmental	**Religious Studies**
Interdepartmental	**Science, Technology and Society**
Interdepartmental	**Sociology**
Interdepartmental	**Student-Defined (by admission)**
Languages, Cultures, and Applied Linguistics	**Applied Multilingual Studies**
Languages, Cultures, and Applied Linguistics	**Arabic Studies**
Languages, Cultures, and Applied Linguistics	**Chinese Studies**
Languages, Cultures, and Applied Linguistics	**French and Francophone Studies**
Languages, Cultures, and Applied Linguistics	**German Studies**
Languages, Cultures, and Applied Linguistics	**Hispanic Studies**
Languages, Cultures, and Applied Linguistics	**Immersive Technologies in Arts and Culture**
Languages, Cultures, and Applied Linguistics	**Japanese Studies**
Languages, Cultures, and Applied Linguistics	**Russian Studies**
Philosophy	**Ethics**
Philosophy	**Linguistics**
Philosophy	**Logic and Computation**
Philosophy	**Philosophy**
Philosophy	**Rationality, Uncertainty, and Choice: Formal Methods**
Philosophy	**Societal & Human Impact of Future Technologies**
Psychology	**Cognitive Neuroscience**
Psychology	**Psychology**
Social and Decision Sciences	**Behavioral Economics**
Social and Decision Sciences	**Decision Science**
Social and Decision Sciences	**Policy and Management**
Social and Decision Sciences	**Data Science in Society**
Statistics and Data Science	**Statistics**

Multiple Degrees

"Multiple degrees" is defined as more than one undergraduate degree granted by the university (whether simultaneous or sequential). One diploma is awarded for each degree; each degree has one primary major associated with it, and the possibility of an additional major and/or minor.

Dietrich College undergraduate students who wish to earn an additional undergraduate degree with a primary major also from Dietrich College must:

- Satisfy all requirements for the primary major to be linked to the additional degree.
- Complete at least 90 units beyond the total number of units required for the first degree. If the major associated with the additional degree requires less than 90 units, the student would earn additional elective units to reach the 90-unit minimum. If the major associated with the additional degree requires more than 90 units, the student would perforce exceed the 90-unit minimum in order to fulfill all of the requirements for the additional degree’s primary major.
- Comply with Carnegie Mellon's Statute of Limitations Policy: All units required for an undergraduate degree, whether earned in residence, transferred from another institution or granted via advanced placement, must have been earned within eight (8) years prior to the date on which the degree is granted.

Non-Dietrich College undergraduate students at Carnegie Mellon who wish to earn an additional undergraduate degree with a Dietrich College primary major must complete all of the requirements listed above, plus any portion of the Dietrich College general education program not already fulfilled by prior undergraduate course work.

Bachelor of Arts & Bachelor of Science

Some Dietrich College majors lead to a Bachelor of Arts (B.A.) degree and others lead to a Bachelor of Science (B.S.) degree option. In some majors students may choose between a B.A. and a B.S. degree. B.A. degree programs usually require less course work in technical and/or quantitative disciplines, and more depth and breadth in various humanities and social science fields, and (in some cases) the arts. In contrast, B.S. degrees are offered in majors requiring more technical, quantitative or scientific competencies.

Dietrich College General Education Program

*For students entering prior to Fall 2021, click here (https://www.cmu.edu/dietrich/gened/previous-curriculum/) for the catalog description of the General Education Requirements.

For students entering Fall 2021 and later*

www.cmu.edu/dietrich/gened (https://www.cmu.edu/dietrich/gened/)

The Dietrich College General Education curriculum (GenEd) provides robust training and knowledge that complements and strengthens the skills learned in a student’s primary major. The GenEd program contains several unique features including: 1) the anchoring of the curriculum on an explicit set of measurable learning outcomes; 2) a focus on creative multi and interdisciplinary approaches to complex problems; 3) the integration of instruction in core competencies like writing and data science across the entire four-year curriculum; 4) ensuring holistic advising is available to every Dietrich student; 5) the expansion of experiential learning opportunities through research and creative inquiry, paid internships opportunities, study abroad, and community engagement; and 6) the commitment to iterative program-level assessment that includes direct measures of student learning.

The GenEd is built on the foundation of 15 high level learning areas and nearly 50 specific student learning outcomes that guide the program. More information about the learning areas can be found on our GenEd website.

Curriculum Requirements

The GenEd curriculum requirements total just above one third of a student's overall degree requirements:

Category Type	Units Required
Foundations	54
Disciplinary Perspectives	42
Special Seminars	18
Experiential Learning Activity	1
TOTAL GENERAL EDUCATION	**115**

Course Categories

1. **Foundations (54 units total)**

There are six (6) foundations requirements, designed to teach both competencies that transcend disciplinary boundaries and the foundational knowledge and skills particularly important for Dietrich College students to acquire.

Required in Year 1	Units Required
Communication	9 units
Data Analysis	9 units

The Communication requirement may be satisfied through one of the following options:

1. 76-101 (Interpretation and Argument) or 76-102 (Advanced First-Year Writing)
2. Choose 2 mini courses: 76-106 (Writing about Literature, Art, and Culture), 76-107 (Writing about Data), or 76-108 (Writing about Public Problems).

The Data Analysis requirement must be satisfied through the completion of 36-200 (Reasoning with Data). Advanced Standing (AP, IB, Cambridge, Transfer) credit will be accepted for this requirement.

Required in Years 1-4	Units Required
Computational Thinking	9 units
Contextual Thinking	9 units
Intercultural and Global Inquiry	9 units
Scientific Inquiry	9 units

A list of courses for each of the above requirements can be found on the GenEd website.

2. Disciplinary Perspectives (42 units total)

There are five (5) disciplinary perspectives requirements, designed to provide a broad reflective understanding of disciplines both within and outside of the College.

Required in Year 1	Units Required
Humanities	9 units
Social Sciences	9 units

Required in Years 1-4	Units Required
The Arts	9 units
Logic/Mathematical Reasoning	9 units

Required in Years 1-4 (6 units in one of the following three disciplines):
Design
Business
Engineering

A list of courses for each of the above requirements can be found on the GenEd website.

3. Special Seminars (18 units total)

The Special Seminars and Topics offer opportunities for students to engage in high impact learning practices to ensure transformative and integrative learning.

Required in Year 1	Units Required
Grand Challenge Seminar	9 units

Required in Years 1-3	Units Required
Perspectives on Justice and Injustice	9 units

4. Experiential Learning Activity (1 unit total)

The Experiential Learning Activity provides students with the opportunity to extend their learning beyond the classroom. This may include completing an internship, undergraduate research, community engaged learning, work-based learning or study abroad. This requirement can be fulfilled anytime after the first semester. Several existing courses fulfill this requirement. The experience must be approved in advance by the Experiential Learning team.

A list of courses for each of the above requirements can be found on the GenEd website.

College Services and Programs

The educational programs in Dietrich College are complemented by a number of services, special programs, centers, and computing facilities.

Dietrich College Senior Honors Program

Joseph E. Devine, *Director and Associate Dean for Undergraduate Studies*
Location: Baker Hall 154F

From its inception in 1982, the Dietrich College senior honors program (http://www.cmu.edu/dietrich/undergraduate/programs/shp/) has provided outstanding undergraduate seniors with the opportunity to work individually with faculty members throughout the university on original research and creative projects. Admission is based on achievement of a cumulative QPA of at least 3.50 in one's major and 3.25 overall, endorsement of a thesis proposal by the faculty member who will serve as thesis advisor, and department head approval. Honors students enroll in an honors thesis course sequence for both semesters of the senior year (9 units per semester). Upon successful completion of the honors thesis, a student qualifies for graduation with Dietrich College Honors, and will have this designation as well as the thesis title noted on the final transcript.

The Honors Research Scholarship Program (https://www.cmu.edu/dietrich/students/undergraduate/funding/dietrich-honors-fellowship/) is an optional component for students who have applied and been accepted into the college's Senior Honors Program. Financial support through a stipend and related funds for research-related expenses allows scholars to spend the summer before their senior year undertaking early-stage research and development of their thesis topics. Students apply for this scholarship program in the spring of the junior year, simultaneous with submission of an application and thesis project proposal for the Dietrich College Senior Honors Program.

Community Engagement Fellowship

Kimberly Piatt, *Director of Experiential Learning*
Location: Baker Hall 160
https://www.cmu.edu/dietrich/students/undergraduate/programs/community-engagement-fellowship/index.html (https://www.cmu.edu/dietrich/students/undergraduate/programs/community-engagement-fellowship/)

The Dietrich College Community Engagement Fellowship was launched in Fall 2022 and provides students with the opportunity to develop their leadership skills while also learning how to create positive change in their communities. The program spans 5 semesters - Fall, Spring, Summer, Fall, Spring during which students complete a combination of coursework and experiential learning activities. The program curriculum includes:

- 66-148 (3 Units): Fall Semester: Introduction to Community Engagement
- 66-214 (6 Units): Spring Semester: Connecting with the Pittsburgh Community
- 66-300 (6 Units): Fall Semester: Using Collective Leadership to Pursue Community Goals
- 66-403 (6-9 Units): Spring Semester: Community Engagement Fellowship Capstone Course

At the end of the fellowship, students will engage in a capstone project during which they connect their specific area of passion to what they have learned through the fellowship. This project is flexible and will depend on the student. Students will be expected to present their capstone project to a panel of stakeholders.

Students in the fellowship receive exclusive access to courses and are able to build fruitful relationships with a cohort of peers and community leaders. Students also receive $3,000 to support their involvement in the community. Additional opportunities, like board membership, conference attendance and others are also offered as part of the experience.

The application process for each 12-student cohort occurs in the Spring. Any student with a primary major in Dietrich or those pursuing a BHA degree may apply. Students should be in good academic standing but students may request an exception by speaking with the Director of Experiential Learning. Students interested in applying must have at least 2 years as an undergraduate student remaining so that they are able to complete the full sequence of courses.

Humanities Scholars Program

Therese Tardio, *Director*
Location: Posner Hall 252
www.cmu.edu/dietrich/hsp (https://www.cmu.edu/dietrich/hsp/)

The Humanities Scholars Program invites a small cohort of students – usually no more than twenty – to work together to investigate the issues that confront contemporary society. Students are invited to join the program at the time of admission based on the strength of their interest and background in one or more of the humanities. Students participate in a living-learning community during their first year and take a series of academic seminars that draw upon the expertise of humanities faculty and the broader intellectual depth of the campus throughout their time at CMU. The Humanities Scholars Program sponsors campus-wide programs, often in collaboration with other programs, such as the Center for Diversity and Inclusion, the College of Fine Arts, and the Institute for Politics and Strategy. The Humanities Scholars experience culminates in a student’s senior year with a capstone project. Students have the ability to use the resources of the program to further their own research, engage with the community, and develop their own areas of expertise. The program is supported by endowment funding from the university as well as from the Arthur Vining Davis Foundations in order to support outstanding undergraduate research in the humanities at the university. For further information, students should contact the Director, Therese Tardio tardio@andrew.cmu.edu

Quantitative Social Science Scholars Program

Mark Patterson, PhD *Director*
Location: Porter Hall 223 B
www.cmu.edu/dietrich/qsss (https://www.cmu.edu/dietrich/qsss/)

The Quantitative Social Science Scholars Program (QSSS) is designed to help outstanding undergraduates impact society through the use of these advanced quantitative methods. It does so by laying out a structured program of training in advanced quantitative techniques that can be broadly applied across a range of social science disciplines and topics.

In addition to two seminars completed in the sophomore year, students complete coursework in a concentration area of their choice, selecting specialization in econometrics, statistics and regression, choice modeling, quantitative policy analysis, computational modeling, or psychometrics and measurement. Concentration areas typically consist of 3-4 courses each. The program equips students to undertake sophisticated analysis of their own, and features an integrative senior thesis project that applies their methodological training to a research question of their own choosing in collaboration with a faculty member of their choice.

The program recruits students with a range of interests across the social sciences to create a cohesive interdisciplinary learning community. Majors that could fit well with this program include (but are not limited to) economics; behavioral economics, policy and organizations; decision science; policy and management; international relations and politics; statistics; statistics and machine learning. Students may apply for entry to the QSSS program during the spring of the first year. Applications consist of a student transcript, and statement of interest.

Student-Defined Program

Joseph E. Devine, *Director and Associate Dean for Undergraduate Studies*
Location: Baker Hall 154
www.cmu.edu/dietrich/undergraduate/student-defined-majors.html (http://www.cmu.edu/dietrich/undergraduate/student-defined-majors.html)

For students whose educational goals cannot be as adequately served by the curricula of existing programs, the college provides the opportunity to self-define a major or minor. The procedure for establishing such a major centers on a written proposal, submitted to the college dean's office. This proposal consists of two parts:

Program description and rationale: A description of the components of the proposed program of study; a presentation of the objectives of the program of study, why it represents a coherent and (given available faculty, courses, and other resources) viable course of study, and the reason(s) why these objectives cannot be accomplished within one or more of the college's existing programs.

The curriculum: Presentation of a complete outline of all courses that will comprise the requirements for the major or minor, categorized according to that component of the major program to which each belongs (e.g., mathematics prerequisites; research methods; theoretical perspectives; etc.), and second, a semester-by-semester outline that indicates when each course is to be taken (or, for any already taken, when taken). The minimum requirement for graduation is, as with all majors in the college, 360 units of credit.

Proposals and curricula are evaluated for clarity of focus, coherence and depth in related areas, and viability within the context of the college and university offerings. Proposals should generally be developed no later than the sophomore year, and approved majors begin their program generally no later than the junior year.

As with all other Dietrich College majors, Dietrich College student-defined primary majors must fulfill all of the college's general education requirements.

Academic Standards, Regulations and Protocols

Graduation Requirements

Eligibility for graduation in Dietrich College requires that a student:

1. satisfy all Dietrich College general education requirements,
2. satisfy all course requirements in a Dietrich College primary major,
3. achieve a cumulative quality point average of at least 2.00 for all courses taken (or, alternatively, for all courses taken after the 1st year),
4. earn at least 360 units with a minimum of 180 units taken

Graduation with College Honors

Students who successfully complete a senior honors thesis under the auspices of the Dietrich College Senior Honors Program qualify for graduation with Dietrich College Honors.

Double-Counting Courses

Double-counting refers to instances when a course taken to fulfill one requirement counts simultaneously toward a requirement in another major or minor program. While the college encourages study in complementary areas where majors and minors frequently share requirements in common, it also wants to keep clear the meaning and integrity of the labels “major” and “minor.” To preserve the integrity of these definitions, double-counting is permitted in Dietrich College on a very limited basis, and only in those instances when the course(s) in question represent only a small portion of the second program.

The college and its departments have developed program-specific guidelines for this practice that appear throughout the Dietrich College section of this catalog, and particularly in the case of major and minor programs that students frequently pursue in combination.

Dietrich College Credit Policy for Non-Carnegie Mellon Courses

The following policies govern the practice of Dietrich College undergraduates taking courses elsewhere and requesting that credits for these courses transfer to their Carnegie Mellon University academic record. Courses taken elsewhere will be considered for transfer credit if the institution offering them is fully accredited, and if the courses in question are judged to be acceptable for the purposes proposed by the student.

Approval

Dietrich College undergraduates who wish to take courses at another institution and request that credits for these courses transfer to their Carnegie Mellon University record should familiarize themselves with Dietrich's transfer credit policies (http://www.cmu.edu/dietrich/advisory-center/transferring/cmu-course-credit.html) . Students must receive approval before taking any courses at another institution in order to guarantee that they will receive transfer credit upon successful completion of the course(s).

Limits

Undergraduate students may take a maximum of 180 units and transfer these back for credit toward the Carnegie Mellon degree.

Exceptions

These limits do not apply to courses and credits taken through cross-registration via the Pittsburgh Consortium for Higher Education (PCHE), and approved study abroad or exchange programs. Exceptions to these restrictions may be made only by way of written petition to the Dietrich College Office of Undergraduate Studies.

In general, approved courses taken elsewhere will transfer as elective credit, unless otherwise approved by the college or relevant academic department.

Grades

Courses taken elsewhere must be taken for a regular letter grade (not pass/no credit or pass/fail) in order to be granted transfer credit. As a matter of college policy, Dietrich College students must earn a final grade of at least "C" in order for the credit to transfer. A “C-” grade is not transferable when its equivalency is below a 2.00 on a 4.00 scale, or 70%. In cases when courses proposed for transfer credit are to apply to requirements in a Dietrich major or minor program, the program's department may set a higher minimum final grade in order for credit to transfer. Only units, not grades, transfer for courses taken elsewhere, and thus do not affect a student's Carnegie Mellon QPA. Ungraded or pass/fail courses may receive credit if the transcript key indicates that the mark represents a grade of C or better. Students should consult their academic advisor before taking courses at another institution for which they want to receive transfer credit.

External Transfer Students

A candidate for the bachelor's degree must complete a minimum of 180 units of coursework at Carnegie Mellon. If a bachelor's degree has already been obtained at another institution, courses that count toward that degree may not be used again as transfer credit toward a Carnegie Mellon University undergraduate degree.

Internal Transfer Students

This policy applies retroactively to students who enter Dietrich College through internal transfer. Courses previously approved for transfer credit may be re-evaluated for consistency with relevant Dietrich College or program policies and standards.

Course Overloads

Overloading is defined as taking more than the equivalent of five full-semester courses in one semester; for Dietrich College students, overload means registering for more than 52 units in one semester.

Eligibility to overload is defined as having a QPA of at least 3.25 in the last completed semester, based on a course load of at least 45 factorable units, and a current cumulative QPA of at least 3.00. Students new to the college and university (i.e., first-year students and new external transfer students) may not overload during their first Carnegie Mellon semester.

Eligibility to overload based on QPA does not automatically allow the student to register for an overload. Rather, students must complete an overload petition, and meet with their primary academic advisor to discuss the proposed overload. If approved, the academic advisor will increase the student's unit maximum for the relevant semester.

The first opportunity to register for a course overload is after registration week for the proposed overload semester. Registration week for the spring semester is usually the third week in November; for the fall semester, it is usually the third week in April. Consult the official university academic calendar for the exact dates.

If as a result of final grades for the current semester a student approved to overload for the next semester falls below the QPA overload eligibility criteria, the academic advisor may withdraw the overload permission. Students thus affected are responsible for resolving this in consultation with their academic advisor.

Physical Education and Stuco* Courses

A maximum of nine units of credit for any combination of Physical Education (69-xxx) and StuCo (98-xxx) courses may be counted as credit toward graduation requirements. Physical Education and StuCo courses are not included when calculating a student's QPA or when calculating units to determine eligibility to carry a course overload.

*StuCo (http://www.cmu.edu/stuco/) refers to "student-led courses" — i.e., courses designed by students, and approved to be offered for academic credit.

Internships-for-Credit

An internship-for-credit is a supervised, professional work experience with clear links to a student's academic program, performed primarily or totally outside of a regular course structure, and for which a student earns academic credit. Students doing an internship for academic credit must be registered through the academic department of the faculty member supervising the internship, and must register for the internship course during the term (including the summer) when the internship work is being performed. There is no additional tuition charge for credit-bearing internships that are taken during the academic year as part of a normal, full-time course load. Students registered for internships during the summer will be billed for tuition at the per-unit rate set by the university.

To receive academic credit, the internship:

- must conform to the criteria for internships-for-credit (https://www.naceweb.org/about-us/advocacy/position-statements/position-statement-us-internships/)set by the National Association of Colleges and Employers and the U.S. Department of Labor
- requires the involvement of a Carnegie Mellon faculty sponsor and an on-site supervisor in the design, oversight and evaluation of the internship;
- must include regular or periodic meetings between the student, the faculty sponsor, and/or the internship site supervisor to monitor progress and offer feedback on student performance;
- requires an end-product for submission to the faculty sponsor. This usually takes the form of a paper, but may also include a presentation, or some other approved form;
- may be taken for a regular letter grade or pass/no credit as per the policy of the department through which the internship course is taken. With department approval, the internship may be counted toward program requirements.
- can vary from 3-18 units in any one semester, and is limited only by the college rule of a maximum of 27 units of internship credit that can be applied to graduation requirements.

Additional policies and practices regarding internships-for-credit vary among the college's academic departments. Departments are not obligated to allow internship credit for its majors, and are free to determine whether an internship may be used to fulfill requirements or serve only as an elective. An internship-for-credit is a graded experience. Each department will determine appropriate criteria for the grade if an internship is approved for credit.

Credits for internships are generally earned according to the following scale:

- 9 units = the equivalent of 1 day (9-12 hours) per week during a full semester
- 18 units = the equivalent of 2 days (12-20 hours) per week during a full semester

A Dietrich College student may not earn more than 18 units of internship credit during a single semester or count more than 27 units of internship credit toward fulfillment of graduation requirements.

In instances when the internship sponsor requires that a student receive academic credit from the home institution, the student should contact the Dietrich College Associate Dean for Undergraduate Studies for information and advice about available options.

Dietrich College Dean's Honor List

Each semester the college recognizes those students who have attained outstanding semester quality point averages by naming them to the Dietrich College dean’s honor list.

Students who complete at least 45 factorable units and attain a semester QPA from 3.50 through 3.74 are named to the Dean’s List, with Honors; if the semester QPA is 3.75 or higher, students are named to the Dean’s List, with High Honors.

Students who complete at least 36 or up to 44 factorable units and attain a semester QPA of 3.75 or higher are named to the Dean’s List, with Honors.

In addition, it is generally the case that students are not eligible for the dean's list who receive one or more "Incomplete" grades at the time when final semester grades are recorded.

Transferring into Dietrich College

Students exploring the possibility of transferring to the Dietrich College of Humanities and Social Sciences must first have satisfied all the appropriate transfer criteria (https://docs.google.com/document/d/1GBIMIbGvOHizq42NgGMJx0lFbYLAkP95/edit/?usp=sharing&ouid=111780354501420821086&rtpof=true&sd=true) and met with the relevant academic advisor (https://www.cmu.edu/dietrich/gened/fall-2021-and-beyond/meet-the-advisors/) before applying.

Students may then submit an application to transfer (https://docs.google.com/document/d/1HuvbnnXQ5F-nl1jy_ColFkZHk3MrV9iqn_wUo4UZ-N0/edit/?usp=sharing) into Dietrich College, which will be reviewed by the Director of Advising in consultation with the relevant academic department. Decisions regarding transfer requests will be based on evidence of adequate prior academic performance and on the applicant's prospects for success in the college and intended major.

Upperclass students can submit an application for transfer at any time. However, first-year students can submit an application for transfer to Dietrich College only after mid-semester grades have been posted in the second semester of their first year.

Course Failures and Course Repetitions

Students who fail a required course must repeat and pass it (or take and successfully complete another approved course that fulfills the requirement). If a failed course is a prerequisite to more advanced course work within a particular course sequence, the failed course must be repeated before moving on to the higher level course.

Failed courses that are repeated and passed, or courses that are passed but repeated in order to obtain a higher grade, remain on the student's record and are included in calculating the student's QPA. Students who repeat a course that they have already passed will not be able to apply the second set of units for the course toward graduation requirements.

Academic Actions

Dietrich College is committed to ensuring that students are able to identify their personal, academic and professional goals; seek out and utilize resources to achieve those goals; and reflect on and refine those goals from matriculation to graduation. At the end of each semester, a student's academic progress and performance is reviewed to determine standing in the next academic semester. Academic actions are designed to support student success and create opportunities for students to reflect and utilize additional campus resources.

In order to maintain good academic standing, Dietrich College students must attain at least a 2.0 minimum quality point average for each semester (as well as cumulatively), and also make and maintain adequate progress toward completing their degree requirements. For purposes of academic standing, default grades for incomplete grades are considered in QPA calculations. Adequate progress towards graduation means that students are successfully completing at least 80% of attempted units in a semester. Grades of N, W, or R grade do not count as completed units.

Academic Concerns

Academic concerns serve to alert the student that the college is concerned about their academic progress and/or one or more actions they have taken or failed to take. A student will receive a notice of academic concern when their academic performance does not meet the minimum standard of 2.0 or they are not making adequate progress toward completing their degree requirements. In addition, a student may receive a notice of academic concern for matters such as repeatedly failing required courses or repeatedly failing to attain minimum-level passing grades in prerequisite courses; failing to complete C@CM by the end of the first semester; failing to make sufficient progress through their declared primary major or the general education program; or receiving multiple incomplete grades over two consecutive semesters. Students who receive a notice of academic concern must meet with their advisor to discuss support resources, review their progress, and plan adjustments as needed.

Academic Warning

A student who has been issued an academic concern in the previous semester is placed on academic warning when their academic performance does not meet the minimum standard of 2.0 or adequate progress toward completing their degree requirements is not being made. All Dietrich students have the potential to be successful and academic warning is meant to signify to the student the college's desire to help them get back on track so they can achieve their goals. The term of academic warning is at least one semester and students with an academic warning are not permitted to overload. The Student Success Plan process outlined in the academic warning letter has been designed to notify students of specific academic requirements and identify avenues of support to help students succeed.

A student is removed from academic warning and returned to good academic standing when both the semester and cumulative quality point averages meet at least the stated minimum, and when adequate progress toward completing degree requirements is being made. A student who has had one semester on warning and is not yet meeting minimum requirements but is making significant progress may be continued on academic warning.

Academic Suspension

Academic suspension is the usual action taken when a student already on academic warning fails to meet the minimum semester or cumulative requirements. The minimum period of academic suspension is at least one and typically two semesters (not including summer). During their academic suspension, a student will work with their advisor to reflect on the circumstances leading up to the suspension, identify the issues that prevented them from achieving academic success, and take actions to address these issues to ensure a successful return and sustained recovery during their CMU career. Such actions could include a work or internship experience, academic coursework at another college or university, and/or other supportive services as appropriate.

Midway through the semester before a suspended student is eligible to return to the university, the student will be contacted via email by the Associate Dean for Student Success or designee with detailed instructions about the process for requesting approval to return and re-enrollment.

Once cleared to return from academic suspension, the Enrollment Services office will be notified and the student will be eligible to enroll. While on academic suspension, students are considered to be on a mandatory “leave of absence,” and are governed by college and university policies concerning such leaves. See subsequent discussions of “Leave of Absence and Withdrawal from the College.”

Students returning from academic suspension do so on final academic warning. Students on final academic warning must achieve a term QPA of at least 2.0 in the two semesters following their suspension. The final warning process ends and students return to good academic standing after receiving semester QPAs of 2.0 or higher for two consecutive semesters and a cumulative QPA of 2.0 or higher. Failure to achieve two consecutive semesters of 2.0 QPAs may result in being dropped from Carnegie Mellon University.

Students who return to good standing after having been academically suspended will return to final warning for one semester if their term QPA does not meet or exceed a 2.0 during their remaining semesters enrolled at Carnegie Mellon.

Academic Drop

A student is dropped for academic reasons from the university and is not permitted to re-enroll when they continue to perform at levels below the minimum set by the college despite the academic warning intervention, and show no indication of being able to reach an acceptable level of performance or maintain steady progress toward completing graduation requirements.

Appeals

Students have the right to appeal Academic Actions decisions to the Dietrich College Dean or appointed designee. All appeals must be received in writing by the deadline printed in the academic standing notification. Additional information about appealing an academic action decision can be found in The Word: Student Handbook (https://www.cmu.edu/student-affairs/theword/academic/appeal-of-grades-and-academic-actions.html).

Student Success & Experiential Learning

Dietrich College Student Success Center

Kelli Lammie Maxwell, *Associate Dean for Student Success*
Location: Baker Hall 160

Dietrich College is committed to ensuring students have the programs, opportunities, and resources necessary to reach their personal and academic goals. We view a college education as more than a major or job training, but as an opportunity for a broad-based development of mind and character, and as an opportunity to build a strong foundation for students’ lives and careers. We work to ensure equitable and transparent policies and procedures for students as well as opportunities for students to connect with faculty and staff throughout the College. Through the Dietrich College Student Success Center and major departments, we provide four-year holistic advising that assists students with academic choices, career development, opportunities outside of the classroom, as well as physical and mental well-being; and through Experiential Learning, we also offer a number of Dietrich College-specific and university-wide opportunities and programs to ensure students have access to high-impact experiences outside of the classroom, like internships, community service, undergraduate research, and study abroad.

Advising

Andrew Ramey, *Director of Advising*
Location: Baker Hall 160
https://www.cmu.edu/dietrich/advisory-center/

The Dietrich College for Humanities and Social Sciences is committed to providing holistic advising for all students. Dietrich College advisors provide individualized support for students on their academic, professional, and personal journeys by connecting them with resources across campus, explaining major, minor, and general education requirements, and challenging students to venture outside their comfort zones to explore new learning opportunities at Carnegie Mellon and beyond. Undeclared first year students are assigned an academic advisor from the Dietrich College Student Success Center upon matriculation. Advisors in the Student Success Center are experts at supporting students, beginning with summer onboarding to prepare students for the transition from high school to college and continuing to provide guidance through to major declaration. After major declaration, students are assigned to an advisor in a department who can assist students in identifying additional opportunities in their major, facilitate connections with faculty, and ensure graduation requirements are met.

Experiential Learning

Kimberly Piatt, Director of Experiential Learning
Location: Baker Hall 160

https://www.cmu.edu/dietrich/gened/fall-2021-and-beyond/experiential-learning/index.html (https://www.cmu.edu/dietrich/gened/fall-2021-and-beyond/experiential-learning/)

Experiential Learning occurs when a student participates in an opportunity that allows them to apply what they are learning in the classroom to a real-world context. This may include internships, undergraduate research with a faculty member, community engaged learning, study abroad or work-based learning through structured consulting projects. Beginning with the class of 2028, all Dietrich College students are required to complete at least one high-quality Experiential Learning activity during their time at Carnegie Mellon University. To support these efforts, the college has a variety of resources available which can be found online (https://www.cmu.edu/dietrich/gened/fall-2021-and-beyond/experiential-learning/), by talking to an academic advisor or by connecting with the Director of Experiential Learning.

Study Abroad

https://www.cmu.edu/dietrich/gened/fall-2021-and-beyond/experiential-learning/study-abroad.html

Opportunities and funding support for study and travel abroad is available through several sources, many administered by the university, and many others available externally. The Office of International Education is the first place to look for information about study or travel abroad, including funding. Two programs housed in Dietrich College are part of this portfolio of study/travel abroad funding programs:

The Department of Languages, Cultures and Linguistics Study Abroad Scholarship Program (https://www.cmu.edu/dietrich/lcal/academics/study-abroad/) offers scholarships to undergraduate students for accredited study abroad programs, limited in some instances to students who are majoring or minoring in a modern language and in other instances to students studying a particular language. Scholarship funds can be applied to tuition, room, board, airfare to the host country and book expenses.

The Dietrich College Study/Travel Abroad Grant Program (https://www.cmu.edu/dietrich/students/undergraduate/funding/study-abroad/) provides support for both traditional study abroad programs, and for non-study abroad experiences such as service learning opportunities, internships, research, or conference travel. The program uses a rolling application schedule for its grant funds, and works closely with the University's Office of International Education in advising students about eligible programs and potential funding sources, completing applications, and preparing for the intended program abroad experience.

Undergraduate Research

https://www.cmu.edu/dietrich/gened/fall-2021-and-beyond/experiential-learning/research.html

Students are strongly encouraged to engage in research under support of a faculty member. Numerous opportunities are available for research positions that are paid or eligible for credit. Students may also explore options from the Office of Undergraduate Research and Scholar Development. Questions about undergraduate research can be directed to an academic advisor or to the director of experiential learning.

Research Training Program

https://www.cmu.edu/dietrich/students/undergraduate/programs/research-training-program.html

The Research Training Program provides students with the opportunity to explore undergraduate research under the mentorship of a faculty member. These occur as one semester, nine-unit courses. The program is open to second-semester first-year students and sophomores with a 3.0 QPA or by petition.

Dietrich College Internship Opportunity Grants

www.cmu.edu/dietrich/students/undergraduate/resources/internship-opportunity-grants.html (https://www.cmu.edu/dietrich/students/undergraduate/resources/internship-opportunity-grants.html)

Dietrich College encourages students to pursue interesting and professionally relevant internship opportunities. Often, however, the very positions that provide students with the most challenging and high-quality work experiences are either unpaid or modestly paid. To help compensate students for taking on work experiences that will be invaluable in helping them define and move toward their career goals, the Dietrich College Internship Opportunity Grant Program seeks to make it more financially possible for students to take advantage of such worthwhile internship opportunities.

Undergraduates with primary majors in Dietrich College, as well as BHA students, are eligible and encouraged to apply. Current sophomores and juniors receive preference. NOTE: Graduating seniors are not eligible.

Students are expected to find their own internships. There are many resources available to help in finding internships, including the Career and Professional Development Center's internship database. Preference for grants is given to students who find positions in the public sector or non-profit agencies.

Dietrich College Pittsburgh Summer Internship Program

https://www.cmu.edu/dietrich/students/undergraduate/experiential-learning/internships/summer-internship-program/info-for-students.html

The Dietrich College Pittsburgh Summer Internship Program is designed for undergraduates who have not yet had a meaningful internship and are seeking to engage and connect with non-profit organizations and start-ups in Pittsburgh. Pittsburgh-area companies and organizations host Dietrich College students for a 10-12 week summer internship, working around 20 hours per week. Students that secure an internship through the program receive a $3,300 stipend provided by the college

Because of the program's strong local focus, all interns are required to work in the City of Pittsburgh during the summer, not remotely, so as to ensure that they get the most out of this experience. Participants are also required to attend professional development workshops hosted by the program and focused on a variety of topics including communication, professional etiquette, giving/receiving feedback, and networking.

Carnegie Mellon University Washington Semester Program

The Carnegie Mellon University Washington Semester Program (p.) (CMU/WSP), sponsored by the Carnegie Mellon Institute for Strategy and Technology (CMIST) (https://www.cmu.edu/cmist/), is a semester-long program in which students live, intern, and take CMU classes in Washington, DC. Full-time undergraduates from any course of study at the university may participate in the program. Students earn forty-eight units for the Carnegie Mellon University Washington Semester Program, interning about twenty-four hours per week in any sector or field of interest within Washington, DC, while taking classes taught by Carnegie Mellon faculty.

Applications (https://www.cmu.edu/ips/washington-dc-semester-program/application.html) are accepted on a rolling admission basis with a final deadline of October 1, for spring semester participation, and March 1, for fall semester participation. Students should contact the Washington Program Manager to discuss the specifics of the program and the deputy director to discuss how the CMU/WSP may fit into their curriculum. Students who participate in the CMU/WSP may qualify for a minor in Politics and Public Policy (https://www.cmu.edu/cmist/academics/undergraduate-programs/minors.html#minor-ppp).

Internships-for-Credit

An internship-for-credit is a supervised, professional work experience with clear links to a student's academic program, performed primarily or totally outside of a regular course structure, and for which a student earns academic credit. Students doing an internship for academic credit must be registered through the academic department of the faculty member supervising the internship, and must register for the internship course during the term (including the summer) when the internship work is being performed. There is no additional tuition charge for credit-bearing internships that are taken during the academic year as part of a normal, full-time course load. Students registered for internships during the summer will be billed for tuition at the per-unit rate set by the university.

To receive academic credit, the internship:

- must conform to the criteria for internships-for-credit (https://www.naceweb.org/internships/)set by the National Association of Colleges and Employers and the U.S. Department of Labor
- requires the involvement of a Carnegie Mellon faculty sponsor and an on-site supervisor in the design, oversight and evaluation of the internship;
- must include regular or periodic meetings between the student, the faculty sponsor, and/or the internship site supervisor to monitor progress and offer feedback on student performance;

- requires an end-product for submission to the faculty sponsor. This usually takes the form of a paper, but may also include a presentation, or some other approved form;
- may be taken for a regular letter grade or pass/no credit as per the policy of the department through which the internship course is taken. With department approval, the internship may be counted toward program requirements.
- can vary from 3-18 units in any one semester, and is limited only by the college rule of a maximum of 27 units of internship credit that can be applied to graduation requirements.

Additional policies and practices regarding internships-for-credit vary among the college's academic departments. Departments are not obligated to allow internship credit for its majors, and are free to determine whether an internship may be used to fulfill requirements or serve only as an elective. An internship-for-credit is a graded experience. Each department will determine appropriate criteria for the grade if an internship is approved for credit.

Credits for internships are generally earned according to the following scale:

- 9 units = the equivalent of 1 day (9-12 hours) per week during a full semester
- 18 units = the equivalent of 2 days (12-20 hours) per week during a full semester

A Dietrich College student may not earn more than 18 units of internship credit during a single semester or count more than 27 units of internship credit toward fulfillment of graduation requirements.

Additionally, the Office of the Vice Provost for Education has options available to students seeking credit for internships. Students may take 99410 in the Fall or Spring or 99411 or 99412 during the summer.

Students seeking to use an internship to meet their experiential learning requirement, or those for whom the internship sponsor requires that a student receive academic credit from the home institution, the student should contact the Dietrich College Director of Experiential Learning for information and advice about available options.

Undergraduate Economics Program Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

73-003 Transfer Credit

All Semesters
This number "holds" a place for an economics transfer credit courses so that these courses can be used in the academic audit system. Student receiving 73-003 credit have met the requirement of earning the equivalent of a "C" in their non-CMU economics course; however, have not earned the equivalent of a "B" which would provide credit for a CMU economics course equivalency.

73-060 Economics: BaseCamp

Fall: 3 units
This short course will launch you into the economics intellectual space and get you thinking like an economist. Through a series of presentations by some of CMU's great economics thinkers you will learn how economic reasoning harnessed to data can lead to better policy design and better business decision making. Presentations may cover the economics of bitcoin and crypto-currency, online market design, financial crises, the future of work, how to become involved in economics research, healthcare, the environment, and other topics. The presentations will be curated by one of CMU's research economists and there will be plenty of opportunities for discussion and debate. The course will also introduce you to the CMU approach to economics and map out the CMU economics major landscape.

73-065 Nudging Behavior in Business and Public Policy

Spring: 3 units
This course applies the insights of Behavioral Economics to inform business and policy decisions. A nudge encourages desired behavior by framing the decision or environment such that various cognitive processes and heuristics are engaged in favor of the desired outcome. The use of this branch of social science has been used successfully by the UK and US governments by the Behavioural Insights Team and Social and Behavioral Sciences Team, respectively. Nudges have also been used effectively by the United Nations, via UNICEF, to address and change a variety of behaviors such as gender violence and sanitation practices. In 2016 the Supreme Committee for Delivery and Legacy founded the Qatar Behavioral Insights Unit (QBIU) and it was incorporated as a foundation under the Qatar Financial Center in 2019. This foundation is known as B4Development (B4D) and would be of interest and importance to CMUQ students. One of the partners of B4D is the Qatar Foundation.

73-102 Principles of Microeconomics

Fall and Spring: 9 units
The course is an introduction to microeconomic principles and how to think like an economist. Market and policy outcomes are largely a function of individual decisions. These questions typically take the form: how much and what combination of things should I buy? When do we want businesses to go bust? Should the government fund student tuition? It's my hope that you'll also start to think about everyday questions from an economic lens: why were bicycles so hard to find this past summer? Is Uber surge pricing just a rip-off? Is illegal streaming bad for consumers? Throughout the semester, we will build a toolkit to allow us to understand how these decisions interact and explain market successes, market failures, and the role of government in the marketplace. Toward the end of the semester, we'll change a few underlying assumptions and address a variety of questions related to strategic interaction. Some of the topics we will begin to introduce include credible threats, commitment problems, and the strategic use of information. Not open to students who have received credit for 73-100. While there are no calculus pre-requisites for this course, students are encouraged to enroll in 73-102 after they've passed 21-111. (Lecture, 2 hours; Recitation, 1 hour).

73-103 Principles of Macroeconomics

All Semesters: 9 units
A one-semester course that teaches the fundamentals of macroeconomics. Students will learn how macroeconomic analysis can explain national economic activity and how government intervention might stabilize an economy. Topics include: defining and measuring national wealth, economic growth, credit markets, unemployment, interest rates, inflation, and the monetary system. Additional emphasis will be paid to: long-term economic development, political economy, financial crises and topics that are central to contemporary macroeconomic debates such as the impact of technological change, migration, and trade on the macroeconomy. Students will access macroeconomic databases, and then use basic statistics to describe and isolate empirical patterns in macro-data. Not open to students who have received credit for 73-100. (Lecture, 2 hours; Recitation, 1 hour).
Prerequisites: 73-104 or 73-102

73-104 Principles of Microeconomics Accelerated

Intermittent: 9 units
This course is a rigorous introduction to microeconomic principles and how to think like an economist. The students are expected to have a successful, prior exposure to fundamental concepts and therefore, the course is at a faster pace than its sister course, 73102, and covers additional topics. The questions typically take the form: What is the optimal consumption pattern for me as an individual? What is the profit maximizing pattern of labor and capital goods for a firm? When do we want businesses to go bust? Should the government fund student tuition? How can firms hire the best match for them? Whay kind of informational asymmetries exist in double-sided markets? It's my hope that the students start to think about everyday questions from an economic lens: Why were cars so hard to find during the pandemic? Is Uber surge pricing just a rip-off? Is illegal streaming bad for consumers? Throughout the semester, we will build a toolkit to allow us to understand how these decisions interact and explain market successes, market failures, and the role of the third parties in the marketplace. Some later topics include credible threats, commitment problems, and the strategic use of information. Knowledge of basic calculus as covered in 21-111 would be helpful for the students. Only students with an AP Microeconomics Exam score of 4 or 5 and qualifying IB/Cambridge Economics exam scores are eligible to enroll in this course. Students without exam credit should enroll in 73-102 Principles of Microeconomics.

73-111 Internship I

All Semesters
By permission of the Undergraduate Economics Program.

73-112 Internship II

All Semesters: 3 units
The goal of this course is for you to reflect critically and constructively on your internship and to help you identify a path that will allow you to build on your internship experiences. By permission of the Undergraduate Economics Program. Open only to declared Economics, Economics and Mathematical Sciences, Economics and Politics, and Economics and Statistics majors.

73-113 Internship III

All Semesters: 3 units
The goal of this course is for you to reflect critically and constructively on your internship and to help you identify a path that will allow you to build on your internship experiences. By permission of the Undergraduate Economics Program. Open only to declared Economics, Economics and Mathematical Sciences, Economics and Politics, and Economics and Statistics majors.

73-153 Economics and Society

Intermittent: 9 units
Our society faces several challenges. Climate change, inequality, social justice, AI and technology are among some of the big ones. In this class, we show how economics or the science of incentives can be used to tackle these challenges. We will talk about the tools needed to approach any challenge and talk about unintended consequences of policies that might seem like they should work. We describe the limits and benefits of markets and use these foundations to talk about the main challenges facing our society and how to address them.
Prerequisites: 21-120 or 21-111

73-155 Models, Math, and Markets

Spring: 9 units
The Markets, Models and Math (M3) course is designed to allow students to reflect on the thought processes that drive science, viewed through the lens of economics. While the economics focus will highlight the way economists use data and models to understand the economic phenomena we see in the real world, the course is also designed to add depth of understanding for students who major in some other discipline, for the simple reason that the things economists study touch on all aspects of human existence, whether it is understanding the cost-benefit trade-offs in architectural design, in the engineering of new products or production technologies, or understanding the grand arc of political discourse in history or the way it has shaped our laws.

73-158 Markets, Models, and Math

Spring: 9 units
The Markets, Models and Math (M3) course is designed to allow students to reflect on the thought processes that drive science, viewed through the lens of economics. While the economics focus will highlight the way economists use data and models to understand the economic phenomena we see in the real world, the course is also designed to add depth of understanding for students who major in some other discipline, for the simple reason that the things economists study touch on all aspects of human existence, whether it is understanding the cost-benefit trade-offs in architectural design, in the engineering of new products or production technologies, or understanding the grand arc of political discourse in history or the way it has shaped our laws. The course is also meant to introduce, in an intuitive way, the kinds of mathematical tools and reasoning that economists use, what the economic historian Philip Mirowski has called "the unreasonable efficacy of mathematics in economic analysis".
Prerequisites: 21-111 and 73-102 Min. grade C

73-199 Experiential Learning in Business and Economics

All Semesters: 3 units
Students will collaborate to create an economic newsletter called "Southwestern PA Economy in a Snapshot," a regional version of the well-known national version produced by the New York Fed (https://www.newyorkfed.org/ medialibrary/media/research/snapshot/snapshot_january2021.pdf?la=en). The newsletter will lay the groundwork for a regular online publication produced by Carnegie Mellon Economics, a combination of data analysis/visualization and economic commentary. The ultimate goal is for the newsletter to be a to-go economics document for policy makers and business leaders in Pittsburgh and the surrounding region. Students will use a combination of data science skills, computer programming skills, and a basic knowledge of the relevant economic data. They will produce a professional, co-authored report that will serve as a valuable resume item for future career prospects. They will form small teams, each of which will create an Economic Commentary that uses the newsletter's data to provide analysis of a contemporary economic issue that is important for the Pittsburgh region. During the tenure of the course, students will also acquire new skills in computer programming, data analysis and economics. The course will "contribute. to a broader body of knowledge" by obtaining, organizing and publicizing regional economic data where no such product currently exists. It will "identify and develop skills needed to approach and tackle a practical problem or issue." That is, students will take skills obtained in the single pre-req course (Principles of Macroeconomics) and combine them with skills that almost all 1st year students take in data analysis and produce a professional piece of economic analysis. They will see how their academic education can be applied in way that this useful to business people and policy makers.
Prerequisite: 73-102 Min. grade C

73-230 Intermediate Microeconomics

Fall and Spring: 9 units
This course builds on the Principles of Economics course. It focuses on the following topics: theory of the consumer, theory of the producer, perfectly competitive market equilibrium, imperfect competition, and market failures due to asymmetric information such as adverse selection and moral hazard. (Lecture, 3 hours; Recitation, 1 hour).
Prerequisites: (21-256 or 21-269 or 21-259 or 21-268 or 21-254) and (73-100 or 73-102 or 73-104)

73-240 Intermediate Macroeconomics

Fall and Spring: 9 units
Through macroeconomic models built upon microeconomic foundations, insights are developed into economic growth processes and business cycles. Topics include aggregation and measurement, national income, business cycle measurement, economic welfare theorems and social inefficiencies, the effect of government fiscal policy upon employment and productivity, and the relationship between investment, interest rates and economic growth. (Lecture, 3 hours; Recitation, 1 hour). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (73-100 or 73-102 or 73-104) and 73-103 and (21-259 or 21-254 or 21-256)

73-255 Independent Study in Economics

Fall and Spring
The Independent Study course in economics allows students to pursue their own research interests in any of a variety of topics in economics. A typical independent study course involves a semester long project under the supervision of an appropriate faculty advisor. The nature and scope of the project are determined by the student and faculty advisor; the project proposal must be approved by an Undergraduate Economics Program staff member. Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: 21-120 and 73-160 Min. grade C

73-258 Developing Blockchain Use Case

Intermittent: 6 units
Blockchains, or distributed ledger and consensus technologies, hold tremendous promise for improving markets and organically handling private, secure data. As CMU develops its own blockchain and token and #8212;-CMU Coin and #8212;-a central concern is to determine the set of applications that such technology would be most useful for. This course is designed for students to propose and, potentially, develop applications or use cases for a campus blockchain. http://tinyurl.com/cmucoincourse (http://tinyurl.com/cmucoincourse/) The course begins with a brief introduction to blockchain using Bitcoin as an example of a blockchain protocol. We will examine the market failure Bitcoin was intended to resolve as well as the role of cryptography and distributed systems in enabling this new technology to create societal value. The course will go on to discuss the boundaries of the role of cryptography in blockchain. Next, we will use these tools to evaluate existing, real-world blockchain use cases with an eye towards developing our own applications of these emerging technologies. Along the way, we will learn practical development skills in distributed ledger technologies to understand blockchain programming and application development. Finally, students will propose their own blockchain use cases for CMU's own proprietary blockchain. No formal prerequisites, but familiarity with programming is highly recommended.

73-265 Economics and Data Science

All Semesters: 9 units
This course is at the intersection of economic analysis, computing and statistics. It develops foundational skills in these areas and provides students with hands-on experience in identifying, analyzing and solving real-world data challenges in economics and business. Students will learn the basics of database and data manipulation, how to visualize, present and interpret data related to economic and business activity by employing statistics and statistical analysis, machine learning, visualization techniques. Students will also be taught a programming language suitable for data science/analysis. Databases will include leading economic indicators; emerging market country indicators; bond and equity returns; exchange rates; stock options; education and income by zip code; sales data; innovation diffusion; experimental and survey data and many others. Applications will include analyzing the effectiveness of different Internet pricing strategies on firm sales, the impact of taking online classes on a worker's earnings, the relationship between regional employment and trade policies; constructing investment risk indices for emerging markets; predicting employee productivity with machine learning tools; assessing health (sleep and exercise) improvements associated with wearable technologies (e.g. FitBit). Additionally, the course will provide students with communication skills to effectively describe their findings for technical and non-technical audiences. Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (15-259 or 36-219 or 36-200 or 36-247 or 36-225 or 36-220 or 21-325 or 36-218 or 36-217 or 36-207 or 36-202 or 70-207 or 36-201) and (73-102 or 73-104)

73-274 Econometrics I

Spring: 9 units
Data tools are important in guiding decisions and strategies for individuals, businesses, and policymakers. This course will prepare you for data-driven decision making, providing both theoretical backgrounds and empirical illustrations of the techniques that are necessary to cope with real-world (imperfect) data. Specifically, the course covers tools and methods for estimating economic relationships, testing economic theories, and evaluating business and government policy. This course builds on either of the two Statistical Reasoning courses (36-200/201) and the Economics and Data Science course (73-265), and it sets underpinnings for Econometrics II (73-275) for more advanced tools and insights for business and economics data analyses. Students pursuing the ECOMTH or MTHECO degrees may enroll in 73-274 after the completion of 36-225. Minimum grade of "C" required in all economics and statistics pre-requisite courses.
Prerequisites: (21-254 or 21-256 or 21-259 or 21-269 or 21-268) and 73-265 Min. grade C and (73-230 Min. grade C or 73-240 Min. grade C)

73-315 Market Design

Intermittent: 9 units
In this course, we consider the design of various market mechanisms. We learn the typical causes of market failures and why we need to design new markets. For each topic, we start with a case study of a problem, develop a theory to address it, and consider its possible solutions. The class is roughly divided into three parts: matching, auctions, and further topics. In the first part, we study markets where there is no money and no prices (matching markets). Instead, we have people preferences over possible matching outcomes. Examples include placing doctors in residency positions, assigning students to schools, and assigning kidneys to transplant patients. We will learn algorithms that have desirable theoretical properties and are often used in practice. In the second part, we consider the problem of allocating of single or multiple goods (a house, a painting, or the rights to a natural resource such as oil or timber) using auctions. We discuss how different types of auctions work in theory and practice. We will look at the auctions used in financial markets to sell treasury bills, the auctions used by Google, Microsoft and Facebook to sell advertising, and the auctions used by governments to sell radio spectrum licenses. In the third part, we consider further important topics of market design. We will look into problems of high-frequency trading, digital markets, the allocation of refugees among European countries, and proposals to fix market for carbon pollution permits. An important goal of the course is to show how recent achievements of game theory and mechanism design lead to important practical applications and to inspire you to use these ideas in your life and workplace. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-254 or 21-259 or 21-256 or 21-269 or 21-268) and 73-230 Min. grade C

73-327 Advanced Topics In Macroeconomics And Real Business Cycles

Intermittent: 9 units
For analysts and decision makers in a variety of positions, such as business managers and government policy makers, a thorough understanding of the economy as a whole helps to make well-informed decisions. Examples of important knowledge about the economy are its sources of growth, the main impulses that cause the economy to fluctuate over time and enter into booms and recessions, the way in which these impulses propagate over time, and the state of the economy in general. The main objective of this course is to lay the foundation for such an understanding and present a framework within which we can (and will) evaluate a variety of aggregate phenomena. Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-269 or 21-259 or 21-256) and 73-240 Min. grade C

73-328 Health Economics

Fall: 12 units
This course will teach the student to use economic analysis to understand critical issues in health care and and health policy. We will address issues such as the following: 1. What factors best explain the level and rate of growth of U.S. health expenditures? 2. Does the recent high rate of growth of U.S. health care expenditures make U.S. firms less competitive in international markets? 3. What are some of the likely consequences (intended and unintended) of the proposed reforms to Medicare? 4. Can physicians induce demand for their services? 5. What are the impacts of managed care on the health care system? 6. Do strong affiliations between physicians and health plans hurt competition? (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses. Junior standing required.
Prerequisites: 21-120 and (73-102 or 73-104)

73-332 Political Economy

Spring: 9 units
The Political Economy course looks at how groups within society organize for self-governance. The course will begin with an overview of the ways groups of individuals organize for collective action by examining different types of political institutions, the role these institutions play in different contexts, and the economic and strategic micro-foundations that give rise to these institutions. We will then examine the empirical evidence supporting this taxonomy, leading to a more detailed consideration of institutions that moderate social conflicts. The next part of the course examines basic results in social choice theory: the Condorcet paradox, Arrow's Impossibility Theorem, majority rule, median voter theories, and modern treatments of probabilistic voting models that allow for strategic behavior, misrepresentation of preferences, and policy manipulation. From this basis for understanding collective choice mechanisms, we will then examine how institutions foster cooperation, looking in detail at problems of public goods allocation, redistribution of income, the organization of clubs - interest groups and lobbying associations and #8212;in the private sector, and the organization of legislative activities in the public sector. In our examination of voting and electoral mechanisms, we will look at practical applications of the theory to problems of gerrymandering, voter suppression, and propaganda that feature prominently in contemporary political discourse.
Prerequisites: (73-160 Min. grade C or 73-230 Min. grade C) and (70-207 or 36-201 or 36-200)

73-336 International Energy Market and Sustainable Development

Intermittent: 3 units
This course teaches you about economics of the energy industry by looking at various energy markets. The global energy industry is now more than ever is pressured to be transformed by geopolitical tensions, concerns about climate change, and the mounting pressure for decarbonization. In this course we will discuss how economic decisions in the energy sector can align with principles of sustainability, ensuring that the industry's growth and practices do not compromise the well-being of future generations or harm the planet.

73-337 Business of Blockchain

Intermittent: 9 units
Economics and business strategy is fundamental for the design and development of blockchain use cases. This course will introduce students to foundational economic concepts to help them understand the role cryptocurrencies play in securing blockchains, how different ``tokenomics'' models impact cryptocurrency prices, the different means to create liquidity or resolve illiquidity in decentralized finance (DeFi) applications such as stablecoins, collateralized-lending, yield farming, or automated market making, the roles of Central Bank Digital Currencies, as well as models to evaluate the value-added of blockchain-based versus traditional business propositions. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: (73-104 or 73-102) and 73-103

73-338 Financial Crises and Risk

Fall: 9 units
This course provides an in-depth examination of the causes of financial crises as well as what governments can do to prevent them or at least reduce their cost. The course is designed to to provide an understanding of individual attitudes towards risk and individual decision making about savings and investment under uncertainty, and to use this understanding to evaluate the various economic roles played by financial institutions in helping individuals manage risk, especially those roles which may lead to economic instability and crises. In addition, the course may cover bubbles and swindles, especially when these spillover to the broader macroeconomy; the role of information in banking in normal times and in bank runs; crisis resolution techniques; and the extensive history of attempts to improve regulation so as to reduce the frequency and cost of crises. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-269 or 21-268 or 21-254 or 21-256 or 21-259) and (73-102 Min. grade C or 73-104 Min. grade C) and 73-240 Min. grade C

73-341 Managing through Incentives

Intermittent: 9 units
We live in an exciting age of information and knowledge when inspiring employees within a firm becomes increasing important. Aligning the objectives of workers, managers, and owners by providing them with appropriate incentives becomes an emerging paradigm in the modern business world. In this course, we learn how to reason about incentives between managers and employees, between managers and owners, and within a team of co-workers. We cover a broad range of topics including objective and subjective performance measurements, relative performance evaluations, relational contracts, and executive compensation. The course relies on business case discussions, rigorous theoretical material, and numerous class activities. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-254 or 21-269 or 21-268 or 21-259 or 21-256) and (36-220 or 36-219 or 36-218 or 36-225 or 36-217 or 36-200 or 36-207 or 36-201 or 36-202 or 70-207) and 73-230 Min. grade C

73-347 Game Theory Applications for Economics and Business

Fall: 9 units
An introduction to the theory of non-cooperative games with an emphasis on economic applications. After an initial examination of two-person, zero-sum games, the notion of a Nash equilibrium in an n-person, non-cooperative game is considered. Existence of and refinements to the equilibrium concept are discussed in the context of both normal and extensive form games. Economic applications may include various topics, including Cournot and Bertrand oligopoly models, general competitive exchange equilibrium, and free rider problems. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

73-348 Behavioral Economics

Spring: 9 units
This course introduces students to behavioral economics which is a subfield of economics that incorporates insights from other social sciences, such as psychology, into economic models and aims to explain the anomalies challenging some of the classical economic models. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (36-200 or 36-225 or 36-207 or 36-217 or 70-207) and 21-120 and (73-104 Min. grade C or 73-100 Min. grade C or 73-102 Min. grade C)

73-352 Public Economics

Fall: 9 units
In this course, students analyze the role of governments in market economies and their impact on the behavior and welfare of citizens. Reasons for government intervention in markets are examined in light of some of the economic challenges faced by modern societies in an increasingly globalized marketplace. Topics include: taxation and expenditure policies, externalities and market failure, social security, public assistance and income redistribution programs. There will also be some coverage of the role of local governments in the economy with respect to such issues as crime, urban development and education. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-254 or 21-256 or 21-259 or 21-269) and 73-230

73-353 Financial Regulation in the Digital Age

Spring: 9 units
The financial crisis and the digitalization of the financial markets have focused attention on the role of regulation for our financial system and the broader economy in recent years. Among the settings that are especially important in the digital economy are electronic trading, big data, algorithms, robo investing, winner-take-all economics, securities offerings, property rights and cyber assets. The course will address the foundations of regulation ("why regulate?") from various perspectives within a market economy, highlighting the sources of "market failure" (such as externalities, adverse selection, and natural monopoly) and potential remedies (such as disclosure, taxes and fees, antitrust prohibitions, privacy requirements, price regulation and guarantees). The conflicting goals among regulators (and why we have multiple regulators) and their impact on the meaning of regulation will be considered along with regulatory competition/arbitrage. Portions of the course will tackle relatively broad questions such as: Why regulate? Why could it be beneficial to restrict permitted algorithms? Are our markets rigged? How suitable are antitrust remedies in the digital era? What is the law of unintended consequences? What is the objective of a policy advocate? Are regulators and regulatory policies a systemic risk? How can regulators enhance the predictability and credibility of their policies? Should we bar insider trading? Should regulations be determined and motivated based upon cost-benefit analysis? How can we evaluate the success or failure of particular regulations and whether they have achieved their objectives? To what extent did the Dodd-Frank Act ensure financial stability?(Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-254 or 21-259 or 21-269 or 21-268 or 21-256) and 73-230 Min. grade C

73-359 Benefit-Cost Analysis

Intermittent: 9 units
The evaluation of public private sector projects. The theory of benefit-cost analysis and related techniques, such as cost-effectiveness analysis. Attention is given to such issues as valuing goods and services that are not normally traded in the marketplace (e.g., the value of an individuals life) and the social rate of discount. Applications are considered in detail. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (73-104 Min. grade C or 73-102 Min. grade C or 73-100 Min. grade C) and (36-225 or 36-220 or 36-217 or 36-207 or 36-200 or 36-202 or 70-207)

73-365 Firms, Market Structures, and Strategy

Fall: 9 units
This course is concerned with the economic analysis of industrial markets that are not perfectly competitive. The effects of imperfect competition on firms' decisions (pricing, location, advertising, research and development, among others) are reviewed. Implications of these effects in terms of public policy are also discussed from a variety of perspectives. Finally, applications to actual markets are considered. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-259 or 21-254 or 21-268 or 21-269 or 21-256) and 73-230 Min. grade C

73-366 Designing the Digital Economy

Spring: 9 units
This class analyzes the economics of e-commerce and technology. It will identify the critical features that differentiate the technology firms from traditional industries, and examine the implications for business strategy. The class will discuss topics such as network effects, switching costs, and platform markets. To complement the economic theory, we will also consider a case study of a firm each week. These have three aims: to provide applications for the concepts developed in the lectures; to inform you about different industries; and to help develop your written, rhetorical and presentation skills. Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-254 or 21-256 or 21-259 or 21-269 or 21-268) and 73-230 Min. grade C and (73-407 Min. grade C or 73-265 Min. grade C or 73-274 Min. grade C or 73-374 Min. grade C or 70-208 or 36-226 or 36-220 or 36-208 or 36-202)

73-369 Islamic Economics

Intermittent: 9 units
This course is designed to introduce students to the basics of Islamic Finance. The course will start with an analysis of the Shariah rules that define Islamic Finance. Students will then look at the main investment structures and map these against the traditional conventional banking products. The course wraps up with a critique of complex project finance structures through a Shariah compliance lens to identify the gaps between theory and practice.

73-374 Econometrics II

Fall: 9 units
The material covered in this course extends from the material covered in Econometrics I (73-274). The course will include both the theory behind the methods and a hands-on analysis of actual data, providing students the tools for both research and industry jobs. Theories and methodologies covered will include: nonlinear regression models, qualitative response regression models, panel data estimators, simultaneous-equation models, and time series. (Lecture, 3 hours; Recitation, 1 hour). Minimum grade of "C" required in all economics and statistics pre-requisite courses.
Prerequisites: (21-256 or 21-259 or 21-268 or 21-269 or 21-254) and 73-230 and 73-274

73-408 Law and Economics

Intermittent: 9 units
This course will provide a broad overview of the scholarly field known as "law and economics." The focus will be on how legal rules and institutions can correct market failures. We will discuss the economic function of contracts and, when contracts fail or are not feasible, the role of legal remedies to resolve disputes. We will also discuss at some length the choice between encouraging private parties to initiate legal actions to correct externalities and governmental actors, such aas regulatory authorities. Extensive attention will be given to the economics of litigation, and to how private incentives to bring lawsuits differ from the social value of litigation. The economic motive to commit crimes, and the optimal governmental response to crime, will be studied in depth. Specific topics within the preceding broad themes include: the Coase Theorem; the tradeoff between the certainty and severity of punishment; the choice between ex ante and ex post sanctions; negligence versus strict liability; property rules; remedies for breach of contract; and the American rule versus the English rule for allocating litigation costs. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: 21-120 and (73-102 Min. grade C or 73-104 Min. grade C)

73-415 Data Driven Business and Public Policy Decision Making

Intermittent: 9 units
In this course students will learn to leverage data to inform business and policy decisions. The course will teach students various methods for data description, including techniques of data visualization and statistical techniques. Students will learn how to assess the precision of estimation techniques. The final part of the course covers examples taken from epidemiology, economics, business and public policy. (Lecture, 3 hours: Recitation: 1 hour). Minimum grade of "C" required in all economics and statistics pre-requisite courses.
Prerequisites: (21-269 or 21-259 or 21-268 or 21-256) and 73-230 Min. grade C and 73-265 Min. grade C

73-421 Emerging Markets

Fall: 9 units
The goal of the course is to study the economic and institutional forces that spur or hinder business activity and growth in emerging economies. The course is designed to provide both quantitative and theoretical foundations for the study of emerging markets. On the quantitative side, the course will introduce students to the empirical analysis of the growth forces and obstacles facing emerging markets by providing numerous hands-on opportunities using real-world data. On the theory side, the course will provide an overview of fiscal, trade and exchange rate policies adopted in emerging economies. The course will focus on successful emerging economies such as India, China, S. Korea and Ireland with broader lessons and comparisons drawn from developed countries. The course will also look at distressed economies, such as North Korea and Venezuela analyzing the challenges and opportunities faced by these developing nations today. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (36-207 or 70-207 or 36-200 or 36-202 or 15-259) and (73-104 or 73-102) and 73-103

73-423 Forecasting for Economics and Business

Spring: 9 units
Governments forecast economic indicators (e.g., GDP, job growth, etc.); businesses forecast sales; portfolio managers forecast asset return; the list goes on. Accurate forecasts are critical to robust organizational decision-making. This course will introduce students to modern methods for forecasting in economic and business applications. Topics covered include Bayesian, statistical, and online learning approaches to forecast construction and assessment, univariate and multivariate time series models and algorithms, and principled combination of multiple methods and data sources along with subject matter expertise to improve performance. Methods will be motivated by applications in macroeconomics, technology, marketing, and finance, with cases drawn from forecasting processes in a variety of business and government organizations. Students will implement forecasting methods in R, including in a real data forecasting competition.
Prerequisites: (21-268 or 21-259 or 21-269 or 21-254 or 21-256) and (73-230 Min. grade C or 73-240 Min. grade C or 73-274 Min. grade C)

73-427 Sustainability, Energy, and Environmental Economics

Fall: 9 units
Topics related to sustainability and the environment are increasingly important to businesses, policymakers, and the general public. This course applies the tools of economic analysis to the problems of environmental protection, natural resource management, and energy production and use. The course will begin by introducing students to how an economist approaches problems of market failure commonly found in environmental contexts. Next, we will explore models that characterize solutions to such environmental issues. We will then address questions regarding measurement, policy design, and, finally, we will apply the tools that we have developed during the semester to the problems of climate change, and the optimal management of non-renewable resources. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (73-100 or 73-104 or 73-102) and (36-200 or 36-225 or 36-220 or 36-202 or 36-217 or 70-207 or 36-207)

73-436 Applied Projects for Business and Economics

Intermittent: 9 units
The Jewish Healthcare Foundation strives to make aging a joyful experience. With this vision in mind, a team of students will aim to conduct a market analysis in order to provide a report and presentation to the Foundation on areas such as policy, technology and/or infrastructure that counter aging mobility as a limiting factor. This exercise may cover a review of what exists in the aging space globally and/or specifically in the Pittsburgh community. Of note, in this project mobility may be defined broadly including areas such as transportation, physical limitations, use of technology etc.

73-469 Global Electronic Markets: Economics and the Internet

Fall: 9 units
The information revolution brought about by the Internet is having a dramatic impact on the organization of economic activity. Long-term contractual relationships that once governed corporate procurement are being dismantled as manufacturers use the Internet to market directly to the public. New transportation networks that used to simply move goods from point A to point B are evolving into dynamic inventory pipelines that allow manufacturers to track and even reroute shipments in real time. At the same time, individuals are making use of sophisticated search engines to comparison shop at a scale that would have been physically exhausting even five years ago. We will use the basic tools of economic analysis to understand how and why the changes in information technology are reshaping the economic landscape. (Lecture, 3 hours). Minimum grade standard of "C" applies only to economics courses.
Prerequisites: (21-268 or 21-256 or 21-259 or 21-269) and (73-230 Min. grade C or 73-160 Min. grade C)

73-476 American Economic History

Fall: 9 units
The study of economic history provides important perspective on current economic institutions and policies. A failure to understand the historical evolution of economic institutions or the variety of past economic experience is perhaps the worst shortcoming of many economists. The study of economic history provides an opportunity to test currently fashionable theories against data different from those used in their construction. In fact, this is a course in applied economics. The theories developed in the intermediate courses will be applied to episodes from the past in ways that increase understanding both of the specific historical episodes considered and the economic theories employed. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: 21-120 and (73-230 Min. grade C or 73-160 Min. grade C)

73-495 Advanced Independent Study in Economics

All Semesters
The Independent Study course in economics allows the student to pursue his or her own research interests in any of a variety of topics in economics. A typical independent study course involves a semester long project under the supervision of an appropriate faculty advisor. The nature and scope of the project are determined by the student and faculty advisor. Minimum grade standard of "C" applies only to economics courses.
Prerequisites: (21-259 or 21-269 or 21-256 or 21-268) and (73-230 Min. grade C or 73-240 Min. grade C)

Course Website: http://tepper.cmu.edu/prospective-students/course-page/73495/advanced-independent-study-in-economics (http://tepper.cmu.edu/prospective-students/course-page/73495/advanced-independent-study-in-economics/)

73-497 Senior Project

Fall: 12 units
A fourth-year project course, open only to Economics primary and additional majors with Senior standing. The senior project is a capstone course in economics. The purpose of the course is to showcase the analytical and quantitative skills that you have acquired as an undergraduate at Carnegie Mellon. The course project should reflect some independent applied research that is genuinely your own work. Thus a "book report" or a "literature review" are not sufficient exercises to satisfy this requirement. The following research approaches are acceptable for the research project: an empirical study based on a data set that you put together, an experimental study based on an experiment that you conducted, an analysis of survey data based on a survey that you conducted, a theoretical analysis based on a model that you have developed, based on your own algorithm. Students who write an honor thesis are exempted from this class. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-259 or 21-256 or 21-269 or 21-254) and (73-274 or 73-265 or 73-407 or 73-374 or 36-303 or 36-226) and 73-230 and 73-240

73-500 Tepper College Honors Thesis I

Fall and Spring
Economics majors with outstanding academic records and intellectual promise will be given the opportunity to undertake original research under the direction of individual faculty members. Research topics are selected by students and approved by faculty. Prerequisites: Senior standing in the Economics Program and permission of the Economics faculty. Minimum grade of "C" required in all economics and statistics pre-requisite courses.
Prerequisites: (21-254 or 21-269 or 21-259 or 21-268 or 21-256) and (73-265 or 73-274 or 36-226) and 73-230 and 73-240

73-501 Tepper College Honors Thesis II

Fall and Spring
Economics majors with outstanding academic records and intellectual promise will be given the opportunity to undertake original research under the direction of individual faculty members. Research topics are selected by students and approved by faculty. Prerequisites include: Senior standing in the Economics Program and permission of the Economics faculty. Minimum grade of "C" required in all economics and statistics pre-requisite courses, and a minimum grade of "B" required in Tepper College Honors Thesis I.
Prerequisites: (21-254 or 21-269 or 21-259 or 21-268 or 21-256) and 73-230 and 73-240 and 73-500 Min. grade B and (73-374 or 73-265)

Department of English

Andreea Ritivoi, Department Head
Location: Baker Hall 259
https://www.cmu.edu/dietrich/english/

The Department of English at Carnegie Mellon engages students in the important study of reading and writing as intellectual activities embedded in historical, cultural, professional, technological, and literary practices. Working with experts in their areas, students become effective writers and analysts of various kinds of texts in a range of media, from traditional print documents to film, multimedia, and on-line texts. Faculty use distinctive methods of studying texts, but all share a deep commitment to working in small and intense workshops and seminars to help students learn to become experts in analyzing existing texts, and in producing original and distinctive work of their own.

The English Department offers the following degree programs:

- B.A. in Creative Writing
- B.A. in Film & Visual Media
- B.A. in Literature & Culture
- B.A. in Professional Writing
- B.S. in Technical Writing

All five majors are structured to allow students to balance liberal and professional interests. Students in the **Creative Writing program** focus on analyzing and learning to produce poetic and narrative forms. Students in the **Film & Visual Media program** focus on cultural analysis, writing, production, and digital media. Students in the **Literature & Culture program** focus on the production and interpretation of print texts and other media in their social and cultural contexts. Students in the **Professional Writing program** focus on analyzing and producing non-fiction for a variety of professional contexts. Students in the **Technical Writing program** focus on integrating writing with technical expertise in a chosen area of concentration (*Technical Communication* or *Science & Medical Communication*). In addition to the five majors, we offer five departmental minors as well as two interdisciplinary minors, and we strongly encourage non-majors in the campus community to join us in English courses, beginning with offerings at the 200-level.

Students also get involved in a range of complementary activities, including a reading series of distinguished writers of poetry, fiction, and non-fiction; publishing, editing, and marketing through involvement with *The Oakland Review* and The Carnegie Mellon University Press; writing and editorial positions on the student newspaper, *The Tartan*, and other campus publications. We also offer a strong internship program that places student writers in media, non-profit, arts, corporate, and technical internships before they graduate. The end of every year culminates in a gala event to celebrate our students and their writing achievements in literary, academic, and professional writing. For this event, known as the Pauline Adamson Awards, we invite a well-known writer to do a public reading and then present and celebrate student writing awards in over a dozen categories, all judged anonymously by writing professionals from outside the university.

Majoring in English: The Five English Degree Options

The department of English offers students five degree options:

- The B.A. in Creative Writing
- The B.A. in Film & Visual Media
- The B.A. in Literature & Culture
- The B.A. in Professional Writing
- The B.S. in Technical Writing

Students who wish to broaden their experience with English courses may do so by taking more than the minimum requirements for each major or by combining two of the majors within the department for an additional major in English. Common combinations include, but are not limited to, a B.A. in Professional Writing with an additional major in Creative Writing; a B.A. in Creative Writing with an additional major in Literature & Culture; or a B.A. in Literature & Culture with an additional major in Professional Writing. Due to significant course overlap, students are not permitted to major in both Professional Writing and Technical Writing together. Consult the English Department and the section on “Completing an Additional Major in English” (p. 375) for further detail.

All of the English majors may be combined with majors and minors from other Carnegie Mellon departments and colleges. The English Department advisor can help you explore the available options so that you can choose a major or combination of programs that is appropriate for your interests and goals.

How the Curriculum is Structured

In addition to Dietrich College requirements, English majors complete 11 to 13 courses (99 to 117 units) specifically related to their chosen major within English and structured as indicated below. Please note that courses between majors/minors in the Department of English may not double count, with the exception of the Film & Visual Media major, due to its courses being pulled from multiple programs within English. A maximum of two courses may double count between Film & Visual Media and programs inside the Department of English. A maximum of two courses may double count for programs outside of the Department of English.

Core Requirements for the Specific Major (7 to 10 courses, 63 to 84 units)

Complete seven to ten courses.

The Core Requirements differ for each major and are designed explicitly to provide both breadth and depth within the specific major the student has chosen.

English Electives (3 to 4 courses, 27 to 36 units)

Complete three to four elective courses.

Elective Electives for the majors are designed to add breadth to each student’s study within English and to provide experience with the range of approaches to reading and writing available within the department. Students in all English majors are encouraged to sample widely from the Department’s offerings.

The B.A. in Creative Writing

Carnegie Mellon is one of only a few English departments in the country where undergraduates can major in Creative Writing (CW). In the CW major, students develop their talents in writing fiction, poetry, screenwriting, and creative nonfiction. While studying with faculty members who are writers, CW majors read widely in literature, explore the resources of their imaginations, sharpen their critical and verbal skills, and develop a professional attitude toward their writing. The extracurricular writing activities and a variety of writing internships available on and off campus provide Creative Writing majors with valuable experiences for planning their future. After graduation, our Creative Writing majors go on to graduate writing programs and to careers in teaching, publishing, public relations, advertising, TV and film, freelance writing, and editing.

Students in the CW major are required to take two of the introductory genre writing courses: one in the spring of their first year, and one in the fall of their sophomore year. Choices include: 76-260 Introduction to Writing Fiction, 76-261 Introduction to Writing Creative Nonfiction, 76-265 Introduction to Writing Poetry, and 76-269 Introduction to Screenwriting. In order to proceed into the workshop courses, students must do well in these introductory courses (earn a grade of A or B). Creative Writing majors take four workshops in fiction, poetry, screenwriting, or nonfiction where the students’ work is critiqued and evaluated by peers and the faculty. They also take courses in literature, including a Readings in Forms course where they spend a semester reading extensively in one genre.

Opportunities

During their senior year, students may write a Senior Project or Honors Thesis (if they qualify for Dietrich College honors) under the supervision of a faculty member.

Carnegie Mellon also offers CW majors various extracurricular opportunities for professional development, including internships both on- and off-campus. For example, they may work as interns with the Carnegie Mellon University Press, which is housed in the English Department. The Press publishes scholarly works, as well as books of poetry and short stories by both new and established American writers.

Students may help edit and submit their work for publication to The Oakland Review, a Carnegie Mellon University sponsored and student-run annual journal.

Students also have opportunities to read their works in a series of readings by student writers held in the Gladys Schmitt Creative Writing Center (also known as The Glad) and to hear nationally known authors as part of the Carnegie Mellon Visiting Writers series. Additionally, the English Department offers prizes for students each year in the writing of fiction, non-fiction, poetry and screenwriting. Student writers are celebrated during The Adamson Awards ceremony.

Curriculum

In addition to satisfying all of the Dietrich College degree requirements for B.A. candidates, Creative Writing majors must complete 11 courses in the following areas:

Creative Writing Core (7 courses, 63 units)

Introductory Genre Writing Courses* (2 courses, 18 units):

		Units
76-260	Introduction to Writing Fiction	9
76-261	Intro to Writing Creative Nonfiction	9
76-265	Introduction to Writing Poetry	9
76-269	Introduction to Screenwriting	9

* * A student must earn a grade of A or B in the introductory genre writing class in order to be eligible to enroll in a workshop of that same genre. A student who earns a grade of C in an introductory genre writing course may enroll in a related workshop only with the permission of the workshop professor. A student who earns a D or R in Survey of Forms may not take a workshop in that genre.

Reading in Forms (1 course, 9 units):

		Units
76-362	Reading in Forms: Nonfiction	9
76-363	Reading in Forms: Poetry (or Reading in Forms: Poetry)	9
76-364	Reading in Forms: Fiction	9

Four Creative Writing Workshops (4 courses, 36 units)

Complete four Creative Writing workshops, at least two in a single genre. Workshops in all genres may be taken more than once for credit, except for Literary Journalism. Additionally, if a student has been accepted into the Dietrich College Senior Honors Program and is completing their thesis in the field of Creative Writing, they may use one semester of thesis credit (66-501 Dietrich College Senior Honors Thesis I or 66-502 Dietrich College Senior Honors Thesis II) to fulfill a workshop requirement.

		Units
76-360	Literary Journalism Workshop	9
76-365	Beginning Poetry Workshop	9
76-460	Beginning Fiction Workshop	9
76-462	Advanced Fiction Workshop	9
76-465	Advanced Poetry Workshop	9
76-464	Creative Nonfiction Workshop	9
76-469	Screenwriting Workshop	9

English Electives (4 courses, 36 units)

Complete four additional courses from the English Department's offerings. Two of the four English Electives must be courses that are designated as fulfilling the literature requirement and focus on close reading of literary texts. Please consult the list of courses published each semester by the Department for current offerings. English Electives may include any course offered by the Department at the 200 level or above. Additionally, English Electives can include no more than one course at the 200 level. The remaining English Electives must be at the 300 or 400 level. In choosing Electives, students are encouraged to sample courses from across the Department.

Double Counting

Students may double count up to two courses with other programs outside of the Department of English. **NOTE:** courses being used for the Dietrich General Education requirements do not have a double-counting limit.

Transfer Courses

Students may transfer up to two courses from other non-CMU programs/institutions toward the primary or additional major in Creative Writing or the BHA in Creative Writing, with the exception of one of the two required Introductory Genre Writing courses. If the two-course maximum is met, other related transfer courses will be considered for general education requirements and free electives for graduation. Please see the Dietrich College Advanced Standing and Transfer Credit Policy (https://www.cmu.edu/dietrich/advisory-center/scheduling-classes/ap-and-transfer-credit.html) for more information.

Recommended Curriculum Pathway: B.A. in Creative Writing

This plan is the recommended pathway for completing the B.A. in Creative Writing in four years. While it is not required for students to follow this pathway precisely, it is highly recommended for students to do so, and we recommend students begin the major's courses as early as possible. Students in Dietrich College may declare their primary major as early February 1. Students who have not declared their major in the Department of English may still take courses with us.

Students may also view the four-year plan (also known as a Pathway) for the B.A. in Creative Writing via the Stellic Degree Audit Application (https://www.cmu.edu/es/stellic/).

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
GEN ED: Foundations: Communication Course	GEN ED: Foundations: Data Analysis Course	GEN ED: Foundations: Scientific Inquiry Course	GEN ED: Foundations: Intercultural & Global Inquiry Course
GEN ED: Disciplinary Perspectives: Humanities Course	GEN ED: Disciplinary Perspectives: Social Sciences Course	GEN ED: Foundations: Computational Thinking Course	GEN ED: Disciplinary Perspectives: Logic/Math Course
GEN ED: Grand Challenge Seminar Course	Introductory Genre Writing Course #1	Introductory Genre Writing Course #2	GEN ED: Equity & Justice Course
Free Elective	Free Elective	Reading in Forms Course	Creative Writing Workshop #1
Free Elective	Free Elective	Free Elective	Free Elective

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
GEN ED: Foundations: Contextual Thinking Course	Open for course exploration, requirements for other majors/minors, study abroad, etc.	GEN ED: Disciplinary Perspectives: Additional Discipline Course (Business, Design, Engineering)	OPTIONAL GEN ED: Senior Capstone OR Free Elective
GEN ED: Disciplinary Perspectives: The Arts Course	Open for course exploration, requirements for other majors/minors, study abroad, etc.	Creative Writing Literature Elective #2	Creative Writing Workshop #4
Creative Writing Literature Elective #1	Open for course exploration, requirements for other majors/minors, study abroad, etc.	Creative Writing English Elective #1	Creative Writing English Elective #2
Creative Writing Workshop #2	Open for course exploration, requirements for other majors/minors, study abroad, etc.	Creative Writing Workshop #3	Free Elective
Free Elective	Open for course exploration, requirements for other majors/minors, study abroad, etc.	Free Elective	Free Elective

The B.A. in Film & Visual Media

The Film & Visual Media major trains students through a combination of coursework in:

- visual media,
- film history and analysis,
- screenwriting,
- and production of film and other visual media.

This major offers a comprehensive education in film and visual media, from theoretical framing and historical-cultural contextualization to training skills in both creating and analyzing film, as well as the development of a complex blend of creative, professional and technical competencies.

CMU's Department of English is an ideal home for the Film & Visual Media major due to the department's combination of creative writers, film and media studies scholars, film makers, digital humanities and visual communication researchers.

Curriculum

In additional to satisfying all of the Dietrich College degree requirements for B.A. candidates, Film & Visual Media majors must complete 12 courses in the following areas. **Note:** courses cannot double count between areas. For example, if you take 76-429 Introduction to Digital Humanities for the Digital Media area, you cannot also count that course for your Literature & Culture area.

Required introductory courses (2 courses, 18 units)

Course		Units
76-239	Introduction to Film Studies	9
76-259	Film History	9

Production Courses (2 courses, 18-21 units)

Required Course		Units
76-292	Introduction to Film Production *	9

* Students who have completed 76-239 Introduction to Film Studies and/or 76-269 Introduction to Screenwriting will be given registration preference.

Additional Production Course (options include but are not limited to:)		Units
54-191	Acting for Non-Majors	9
60-110	Foundations: Time-Based Media	10
60-125	IDeATe: Introduction to 3D Animation Pipeline	12
60-141	Black and White Photography I	10
60-218	IDeATe Portal: Real-Time Animation	10
60-220	IDeATe: Technical Character Animation	10
60-245	Portrait Photography	10
60-333	IDeATe: Animation Rigging	10
60-415	Advanced ETB: Animation Studio	10
60-416	Advanced ETB: Documentary Storytelling	10
76-374	Mediated Narrative	9
76-481	Introduction to Multimedia Design	12

Screenwriting Courses (2 courses, 18 units)

Required Courses		Units
76-269	Introduction to Screenwriting	9
76-469	Screenwriting Workshop	9

Digital Media Courses (2 courses, 18-20 units)

Options include but are not limited to:		Units
15-104	Introduction to Computing for Creative Practice	10
60-125	IDeATe: Introduction to 3D Animation Pipeline	12
60-142	Digital Photography I	10
60-242	Digital Photography II	10
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis	10
76-314	Data Stories	9
76-388	Coding for Humanists	9
76-429	Introduction to Digital Humanities	9

Literature & Cultural Studies Courses (2 courses, 18 units)

Course options include but are not limited to the following:

Course		Units
76-203	Literature & Culture in the 18th Century	9
76-207	Special Topics in Literature & Culture	9
76-210	Banned Books	9
76-221	Books You Should Have Read By Now	9
76-232	Introduction to Black Literature	9
76-245	Shakespeare: Tragedies & Histories	9
76-247	Shakespeare: Comedies and Romances	9
76-310	Advanced Studies in Film and Media	9
76-313	Creative Visual Storytelling in Film Production	9
76-314	Data Stories	9
76-337	Intersectional Feminism	9
76-353	Transnational Feminisms: Fiction and Film	9
76-429	Introduction to Digital Humanities	9
76-439	Seminar in Film and Media Studies	9
76-440	Postcolonial Theory: Diaspora and Transnationalism	9
76-448	Shakespeare on Film	9

Topics in Film & Visual Media Studies Courses (2 courses, 18 units)

Course options include but are not limited to the following:

Course		Units
76-312	Crime and Justice in American Film	9
76-339	Topics in Film and Media (Can be taken more than once for credit, provided the course topic is new each time).	9
76-353	Transnational Feminisms: Fiction and Film	9
76-367	Fact Into Film: Translating History into Cinema	9
76-448	Shakespeare on Film	9
76-439	Seminar in Film and Media Studies	9
79-225	West African History in Film	9
79-306	Fact into Film: Translating History into Cinema	9
79-308	Crime and Justice in American Film	9
79-309	The Chinese Revolution Through Film (1949-2000)	9
79-319	India Through Film	6
79-326	Shall We Dance? Culture, Politics, and Movement in the 20th Century	6
79-339	History of Juvenile Delinquency & Juvenile Justice	9
82-215	Arab Culture Through Dialogues, Film, and Literature	9
82-278	Japanese Film and Literature: The Art of Storytelling	9
82-284	Multicultural Pittsburgh: VR Storytelling	6
82-296	From Augustine to Avatars: Personal Narratives Across Media	Var.
82-355	Tpcs in Hispanic Std: Beyond the Film Screen: The Hispanic World Through Film	9

Recommended Courses

While not required, a few courses are recommended as a part of the curriculum. They include:

76-310	Advanced Studies in Film and Media	9
76-323	Text to Screen	9
76-374	Mediated Narrative	9

Double Counting

Students may double count up to two courses with other programs outside of the Department of English. **NOTE:** courses being used for the Dietrich General Education requirements do not have a double-counting limit.

Transfer Courses

Students may transfer up to two advisor-approved courses from other programs outside of Carnegie Mellon University toward the primary or additional major in Film & Visual Media Studies, with the exception of 76-239 Introduction to Film Studies and 76-259 Film History. If the two-course maximum is met, other related transfer courses will be considered for general education requirements and free electives for graduation. Please see the Dietrich College Advanced Standing and Transfer Credit Policy (https://www.cmu.edu/dietrich/advisory-center/scheduling-classes/ap-and-transfer-credit.html) for more information.

Recommended Curriculum Pathway: B.A. in Film & Visual Media

This plan is the recommended pathway for completing the B.A. in Film & Visual Media in four years. While it is not required for students to follow this pathway precisely, it is highly recommended for students to do so, and we recommend students begin the major's courses as early as possible. Students in Dietrich College may declare their primary major as early as February 1. Students who have not declared their major in the Department of English may still take courses with us.

Students may also view the four-year plan (also known as a Pathway) for the B.A. in Film & Visual Media via the Stellic Degree Audit Application (https://www.cmu.edu/es/stellic/).

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
GEN ED: Foundations: Communication Course	GEN ED: Foundations: Data Analysis Course	GEN ED: Foundations: Scientific Inquiry Course	GEN ED: Foundations: Intercultural & Global Inquiry Course
GEN ED: Disciplinary Perspectives: Humanities Course	GEN ED: Disciplinary Perspectives: Social Sciences Course	GEN ED: Foundations: Computational Thinking Course	GEN ED: Disciplinary Perspectives: Logic/Math Course
GEN ED: Grand Challenge Seminar Course	76-310 Advanced Studies in Film and Media (recommended course, but not required)	76-259 Film History	76-469 Screenwriting Workshop
76-239 Introduction to Film Studies (Also counts as GEN ED: Disciplinary Perspectives: The Arts)	Literature & Culture Course #1	76-269 Introduction to Screenwriting	Digital Media Course #1
Free Elective	Free Elective	76-292 Introduction to Film Production	Topics in Film Course #1

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
GEN ED: Foundations: Contextual Thinking Course	Open for course exploration, requirements for other majors/minors, study abroad, etc. OR Topics in Film Course #2	GEN ED: Disciplinary Perspectives: Additional (Business, Design, Engineering)	OPTIONAL GEN ED: Senior Capstone OR Free Elective
GEN ED: Equity and Justice Course	Open for course exploration, requirements for other majors/minors, study abroad, etc. OR 76374 Mediated Narrative (recommended course, but not required)	Topics in Film Course #2 OR Free Elective	76-374 Mediated Narrative (recommended course, but not required) OR Free Elective
Production Elective Course or 323 Text to Screen (which is a recommended course, but not required)	Open for course exploration, requirements for other majors/minors, study abroad, etc. OR Free Elective	Free Elective	Free Elective
Literature & Culture Course #2	Open for course exploration, requirements for other majors/minors, study abroad, etc. OR Free Elective	Free Elective	Free Elective
Digital Media Course #2	Open for course exploration, requirements for other majors/minors, study abroad, etc. OR Free Elective	Free Elective	Free Elective

The B.A. in Literature & Culture

The Literature & Culture Major teaches students how to read, interpret and write persuasively about novels, poems, plays and other imaginative works across a variety of genres and media forms. Along with teaching students the analytical skills and methodological tools to interpret these works, this major teaches the importance of understanding imaginative works within their cultural and historical contexts. In addition, the major is designed to train students in strong professional and academic skills like critical thinking, inductive reasoning and persuasive argumentation that are applicable to other fields of study and a variety of career paths.

Curriculum

In additional to satisfying all of the Dietrich College degree requirements for B.A. candidates, Literature & Culture majors must complete 13 courses in the following areas:

Requirements

13 courses, 117.0 units total

Required Introductory Courses (3 courses, 27 units)

Course		Units
76-26X	Introductory Genre Writing Course (Fiction, Creative Nonfiction, Poetry, or Screenwriting)	9
76-245	Shakespeare: Tragedies & Histories	9
or 76-247	Shakespeare: Comedies and Romances	
76-275	Introduction to Critical Writing	9

200-Level Literature & Culture Courses (2 courses, 18 units)

One course must cover the period of 1830 or before. **NOTE:** a single course cannot double count for both the Required Introductory Courses and the 200-Level Literature & Culture Courses. For example, you cannot count 76-245 Shakespeare: Tragedies & Histories as a *Required Introductory Course* as well as for the *200-Level Literature & Culture Course* for the *1830 or Before* requirement.

Options include but are not limited to:

Courses 1830 or Before		
76-203	Literature & Culture in the 18th Century	9
76-230	Literature & Culture in the 19th Century	9
76-233	Literature and Culture in the Renaissance	9
76-245	Shakespeare: Tragedies & Histories (if not taken as one of the required introductory courses)	9
76-247	Shakespeare: Comedies and Romances (if not taken as one of the required introductory courses)	9

Additonal 200-Level Courses		Units
76-207	Special Topics in Literature & Culture	9
76-236	Major Fiction Then and Now	9
76-278	Japanese Film and Literature: The Art of Storytelling	9
76-282	Disability in Pop Culture	9
76-210	Banned Books	9
76-217	Literature & Culture of the 20th and 21st Century	9
76-221	Books You Should Have Read By Now	9
76-239	Introduction to Film Studies	9
76-241	Introduction to Gender Studies	9
76-242	American Woman Writers	9
76-245	Shakespeare: Tragedies & Histories	9
76-244	Immigrant Fictions	9
76-247	Shakespeare: Comedies and Romances	9
76-259	Film History	9
76-287	Sex & Texts	9

300-Level Literature & Culture Courses (2 Courses, 18 units)

Course options include but are not limited to the following:

Course		Units
76-310	Advanced Studies in Film and Media	9
76-312	Crime and Justice in American Film	9
76-313	Creative Visual Storytelling in Film Production	9
76-314	Data Stories	9
76-317	Contemporary American Fiction	9
76-326	Contemporary Global Literature	9
76-329	Performing Race in Early Modernity	9
76-337	Intersectional Feminism	9
76-339	Topics in Film and Media	9
76-341	Race & Gender in the Age of Jane Austen	9
76-343	Rise of the American Novel	9
76-349	Climate Fictions	9
76-367	Fact Into Film: Translating History into Cinema	9
76-392	Special Topics in Literature & Culture	9

Theory Course (1 course, 9 units)

Course options include but are not limited to the following:

Course		Units
76-337	Intersectional Feminism	9

76-350	Critical Theories about Literature	9
76-376	History of Critical Ideas	9

Rhetoric Course (1 course, 9 units)

Course options include but are not limited to the following:

Course		Units
76-325	Intertextuality	9
76-327	Equity & Communication: Strategies for Institutional Change	9
76-351	Rhetorical Invention	9
76-373	Argument	9
76-384	Race, Nation, and the Enemy	9
76-388	Coding for Humanists	9
76-389	Rhetorical Grammar	9
76-415	Mediated Power and Propaganda	9
76-418	Rhetoric and the Body	9
76-425	Rhetoric, Science, and the Public Sphere	9
76-457	Rhetorical Invention	9
76-473	Rhetoric & the Construction of Race	9
76-476	Rhetoric of Science	9
76-483	Research Methods in Technical & Professional Communication	9
76-492	Rhetoric of Public Policy	9

400-Level Capstone Seminar Course (1 course, 9 units)

Each semester, a 400-level course is designated as the Capstone Seminar. Literature & Culture majors are required to take this course in their final semester. Course options may include but are not limited to the following:

Course		Units
76-408	Culture and Globalization	9
76-410	The Long Eighteenth Century	9
76-423	Transnational Feminisms	9
76-424	Theories of Social Class	9
76-429	Introduction to Digital Humanities	9
76-431	Gender Play in Early Modern Drama	9
76-439	Seminar in Film and Media Studies	9
76-440	Postcolonial Theory: Diaspora and Transnationalism	9
76-445	Milton	9
76-446	Revenge Tragedy	9
76-448	Shakespeare on Film	9
76-450	Law, Culture, and the Humanities	9
76-452	Generations and Culture	9
76-453	Literature of Empire	9
76-467	Crime Fiction and Film	9
76-468	Space and Mobilities	9
76-495	Other People's Words: The History, Theory, and Practice of Interviews	9

English Elective Courses (3 courses, 27 units)

Courses for the English Elective requirement can be fulfilled by choosing any of our 200- to 400-level courses. Students are encouraged to sample courses across our programs.

Double Counting

Students may double count up to two courses with other programs outside of the Department of English. **NOTE:** courses being used for the Dietrich General Education requirements do not have a double-counting limit.

Transfer Courses

Students may transfer up to two advisor-approved courses from other non-CMU programs/institutions toward the primary or additional major in Literature & Culture or the BHA in Literature & Culture, with the exception of the Required Introductory Courses. If the two-course maximum is met, other related transfer courses will be considered for general education requirements and free electives for graduation. Please see the Dietrich College Advanced Standing and Transfer Credit Policy (https://www.cmu.edu/dietrich/advisory-center/scheduling-classes/ap-and-transfer-credit.html) for more information.

Recommended Curriculum Pathway: B.A. in Literature & Culture

This plan is the recommended pathway for completing the B.A. in Literature & Culture in four years. While it is not required for students to follow this pathway precisely, it is highly recommended for students to do so, and we recommend students begin the major's courses as early as possible. Students in Dietrich College may declare their primary major as early as February 1. Students who have not declared their major in the Department of English may still take courses with us.

Students may also view the four-year plan (also known as a Pathway) for the B.A. in Literature & Culture via the Stellic Degree Audit Application (https://www.cmu.edu/es/stellic/).

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
GEN ED: Foundations: Communication Course	GEN ED: Foundations Data Analysis Course	GEN ED: Foundations Scientific Inquiry Course	GEN ED: Foundations Intercultural & Global Inquiry Course
GEN ED: Disciplinary Perspectives: Humanities Course	GEN ED: Disciplinary Perspectives: Social Sciences Course	GEN ED: Foundations: Computational Thinking Course	GEN ED: Disciplinary Perspectives: Logic/Math Course
GEN ED: Grand Challenge Seminar Course	76-245 Shakespeare: Tragedies & Histories (also fulfills the GEN ED: Foundations: Contextual Thinking requirement) if not fulfilled in Fall of First-Year, OR Free Elective)	GEN ED: Equity and Justice Course	200-Level Literature & Culture Course #1
76-247 Shakespeare: Comedies and Romances (also fulfills the GEN ED: Foundations: Contextual Thinking requirement), OR Free Elective	Free Elective	76-275 Introduction to Critical Writing	200-Level Literature & Culture Course #2
Free Elective	Free Elective	76-26x Introductory Genre Writing Course (Fiction, Creative Nonfiction, Poetry, or Screenwriting)	Free Elective

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
GEN ED: Disciplinary Perspectives: The Arts Course	Open for course exploration, requirements for other majors/minors, study abroad, etc.	GEN ED: Disciplinary Perspectives: Additional Course (Business, Design, Engineering)	76-4xx Capstone Seminar
300-Level Literature & Culture Course #1	Open for course exploration, requirements for other majors/minors, study abroad, etc.	300-Level Literature & Culture Course #2	English Elective Course #2
Theory Course	Open for course exploration, requirements for other majors/minors, study abroad, etc.	English Elective Course #1	English Elective Course #3
Rhetoric Course	Open for course exploration, requirements for other majors/minors, study abroad, etc.	Free Elective	Free Elective
Free Elective	Open for course exploration, requirements for other majors/minors, study abroad, etc.	Free Elective	Free Elective

The B.A. in Professional Writing

Professional Writing (PW) combines a professional education with a strong foundation in rhetorical studies. The major prepares students for successful careers as writers and communications specialists in a range of fields, including but not limited to: editing and publishing, government, law, journalism, the non-profit sector, education, public and media relations, corporate communications, advocacy writing, and the arts.

The PW major includes 13 courses: 10 PW Core Requirements + 3 English Electives. The 10 Core Requirements include foundations courses in genre studies, editing, and argument, a professional seminar, plus a cluster of advanced rhetoric and specialized writing courses, all designed to closely integrate analysis and production. Through special topics courses — journalism, web design, advocacy writing, document design for print, science writing, public relations and corporate communications, writing for multimedia — students can pursue specializations while working with faculty who are both experts and practicing professionals in these fields. The 3-unit professional seminar, 76-300 Professional Seminar, which meets weekly during the fall term, provides majors with the opportunity to meet and network with practicing professionals in a range of communications fields. PW majors also gain experience in working on team- and client-based projects and receive focused support to develop a portfolio of polished writing samples to use in applying for internships and employment. Through English Electives in Rhetoric, Creative Writing, and Literary and Cultural Studies, students gain additional practice in the careful reading, writing, and analysis of both literary and non-fictional texts and important insights into how texts function in their historical and contemporary contexts. As a capstone experience, senior PW majors have the opportunity to complete a Senior Project or, upon invitation from the college, a Senior Honors Thesis in Rhetoric or Professional Writing. PW students can also apply for research grants through the Undergraduate Research Office to work on independent research projects with faculty.

While the major appeals to students with strong professional interests, both core and elective requirements develop the broad intellectual background one expects from a university education and prepare students to either enter the workplace or pursue graduate study in fields as diverse as communications, law, business, and education. PW majors also have the opportunity to apply for the Department's accelerated MA in Professional Writing, the MAPW 4+1, which allows them to complete the degree in 2 semesters instead of the usual 3. Because the major in Professional Writing is deliberately structured as a flexible degree that allows a broad range of options, PW majors should consult closely with their English Department advisors on choosing both elective and required courses and in planning for internships and summer employment.Various opportunities for writers to gain professional experience and accumulate material for their writing portfolios are available through campus publications, department-sponsored internships for academic credit, and writing-related employment on and off campus.

PW majors also have the option of taking writing internships for academic credit during their junior or senior year and are also strongly encouraged to seek professional internships throughout their undergraduate years and during their summers. Opportunities in public and media relations, newspaper and magazine writing, healthcare communication, publishing, technical writing, public service organizations, and writing for the web and new media illustrate both internship possibilities and the kinds of employment that Professional Writing majors have taken after graduation.

Curriculum

In addition to satisfying all of the Dietrich College degree requirements for B.A. candidates, Professional Writing majors must fulfill 13 requirements in the following areas:

Professional Writing Core (10 courses, 84 units)

Departmental Core Requirement (1 courses, 9 units):

Introductory Genre Writing Course		
76-260	Introduction to Writing Fiction	9
76-261	Intro to Writing Creative Nonfiction	9
76-265	Introduction to Writing Poetry	9
76-269	Introduction to Screenwriting	9

Professional Writing Core Requirements (4 courses, 30 units):

76-271	Introduction to Professional and Technical Writing	9
76-300	Professional Seminar	3
76-373	Argument	9
76-390	Style	9

Rhetoric/Language Studies Requirement (1 course, 9 units):

Complete one course from a set of varied offerings in Rhetoric/Language Studies as designated each term by the English Department. These courses focus explicitly on language and discourse as objects of study and emphasize the relationships of language, text structure, and meaning within specific contexts. Courses include but are not limited to the following:

Course		Units
76-301	Internship	Var.
76-319	Environmental Rhetoric	9
76-325	Intertextuality	9
76-327	Equity & Communication: Strategies for Institutional Change	9
76-351	Rhetorical Invention	9
76-360	Literary Journalism Workshop	9
76-384	Race, Nation, and the Enemy	9
76-389	Rhetorical Grammar	9
76-415	Mediated Power and Propaganda	9
76-476	Rhetoric of Science	9

Advanced Writing/Rhetoric Courses (4 courses, 36-42 units):

Complete four courses from a set of varied offerings in Advanced Writing/ Rhetoric as designated each term by the English Department. Options include all courses that fulfill the Rhetoric requirement, plus additional courses in specialized areas of professional writing. Students should select courses in consultation with their English Department advisor or the Director of Professional Writing. Courses include but are not limited to the following:

		Units
76-301	Internship	Var.
76-302	Communication Support Tutoring Practicum	6
76-314	Data Stories	9
76-319	Environmental Rhetoric	9
76-351	Rhetorical Invention	9
76-354	Watchdog Journalism	9
76-360	Literary Journalism Workshop	9
76-372	News Writing	9
76-380	Methods in Humanities Analytics	9
76-388	Coding for Humanists	9
76-389	Rhetorical Grammar	9
76-391	Document & Information Design	9
76-395	Science Writing	9
76-415	Mediated Power and Propaganda	9
76-418	Rhetoric and the Body	9
76-425	Rhetoric, Science, and the Public Sphere	9
76-457	Rhetorical Invention	9
76-464	Creative Nonfiction Workshop	9
76-474	Software Documentation	9
76-475	Law, Performance, and Identity	9
76-476	Rhetoric of Science	9
76-481	Introduction to Multimedia Design	12
76-484	Discourse Analysis	9
76-492	Rhetoric of Public Policy	9
76-487	Information Architecture & Content Design (formerly titled Web Design)	
76-494	Healthcare Communications	9
76-496	Research Methods in Rhetoric & Writing Studies (instructor permission required)	9

English Electives (3 Courses, 27 Units)

Complete three courses from any of English Department's offerings (exceptions include 76-270, which is designed for non-majors). One may be at the 200-level or above; the remaining two must be at the 300- or 400-level. Two must be courses designated as Text/Context Electives, which focus on the relationship between texts and their cultural and historical contexts.

Double Counting

Students may double count up to two courses with other programs outside of the Department of English. **Note:** courses being used for the Dietrich General Education requirements do not have a double-counting limit.

Transfer Courses

Students may transfer up to two advisor-approved courses from other non-CMU programs/institutions toward the primary or additional major in Professional Writing or the BHA in Professional Writing, with the exception of the *Departmental Core Requirement* course and the *Professional Writing Core Requirement* courses. If the two-course maximum is met, other related transfer courses will be considered for general education requirements and free electives for graduation.. Please see the Dietrich College Advanced Standing and Transfer Credit Policy (https://www.cmu.edu/dietrich/advisory-center/scheduling-classes/ap-and-transfer-credit.html) for more information.

Recommended Curriculum Pathway: B.A. in Professional Writing

This plan is the recommended pathway for completing the B.A. in Professional Writing in four years. While it is not required for students to follow this pathway precisely, it is highly recommended for students to do so, and we recommend students begin the major's courses as early as possible. Students in Dietrich College may declare their primary major as early as February 1. Students who have not declared their major in the Department of English may still take courses with us.

Students may also view the four-year plan (also known as a Pathway) for the B.A. in Professional Writing via the Stellic Degree Audit Application (https://www.cmu.edu/es/stellic/).

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
GEN ED: Foundations: Communication Course	GEN ED: Foundations Data Analysis Course	GEN ED: Foundations Scientific Inquiry Course	GEN ED: Foundations Intercultural & Global Inquiry Course
GEN ED: Disciplinary Perspectives: Humanities Course	GEN ED: Disciplinary Perspectives: Social Sciences Course	GEN ED: Foundations: Computational Thinking Course	GEN ED: Disciplinary Perspectives: Logic/Math Course
GEN ED: Grand Challenge Seminar Course	76-271 Introduction to Professional and Technical Writing	76-26x Introductory Genre Writing Course (Fiction, Creative Nonfiction, Poetry, or Screenwriting)	GEN ED: Equity and Justice Course
Free Elective	Free Elective	76-300 Professional Seminar	76-390 Style
Free Elective	Free Elective	Free Elective	Text/Context Course #1
		Free Elective	

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
GEN ED: Foundations: Contextual Thinking	Open for course exploration, requirements for other majors/minors, study abroad, etc.	GEN ED: Disciplinary Perspectives: Additional Course (Business, Design, Engineering)	Optional GEN ED: Senior Capstone
GEN ED: Disciplinary Perspectives: The Arts Course	Open for course exploration, requirements for other majors/minors, study abroad, etc.	Advanced Writing/ Rhetoric Course #2	76-373 Argument
Rhetoric/Language Studies Course	Open for course exploration, requirements for other majors/minors, study abroad, etc.	Advanced Writing/ Rhetoric Course #3	Advanced Writing/ Rhetoric Course #4
English Elective	Open for course exploration, requirements for other majors/minors, study abroad, etc.	Text/Context Course #2	Free Elective
Advanced Writing/ Rhetoric Course #1	Open for course exploration, requirements for other majors/minors, study abroad, etc.	Free Elective	Free Elective

The B.S. in Technical Writing

The B.S. in Technical Writing (TW) is one of the oldest undergraduate technical communication degrees in the country with a history that stretches back to 1958. The degree is specifically designed to prepare students for successful careers involving scientific, technical, and computer-related communication, including writing and designing for digital media.

Today's technical communicators have the strong backgrounds in technology, communication, and design needed to enter a broad range of information-based fields, and do work that both includes and goes well beyond writing documents for print distribution. The expanding range of options includes positions that involve organizing, managing, communicating, and facilitating the use of both technical and non-technical information in a range of fields and media.

Technical communicators develop and design web sites, explain science and technology to the public, develop print and multimedia materials, develop information management systems, design and deliver corporate training, and develop support systems for consumer products ranging from software for word processing or personal finances to complex data management systems.

The B.S. in TW recognizes the important changes taking place in communication-based careers and includes two distinctive “tracks,” one in Technical Communication (TC) and one in Scientific and Medical Communication (SMC). Both tracks begin with a common core of foundation courses in print and on-line communication as well as a shared set of prerequisites in math, statistics, and computer programming. The two tracks differ in the set of theory/specialization courses beyond the core, with each track including a specialized set appropriate to its focus.

In both tracks, TW students work on real projects for actual clients, learn group interaction and management skills, and develop a flexible repertoire of skills and strategies to keep up with advances in software and technology. Above all, they focus on developing structures and information strategies to solve a broad range of communication and information design problems.

TW students are able to draw on exceptional resources on and off campus to enhance their education. Most obvious are the course offerings of Carnegie Institute of Technology, the Mellon College of Science, and the School of Computer Science. Additional course offerings in business, organizational behavior, policy and management, psychology, history, and design are also encouraged. As a capstone experience, Seniors have the opportunity to complete a Senior Project or, upon invitation from the college, a Senior Honors Thesis. TW students can also apply for grants and fellowship through the Undergraduate Research Office to work on independent research projects with faculty.

While the major appeals to students with strong professional interests, both core and elective requirements develop the broad intellectual background one expects from a university education and prepare students to either enter the workplace upon graduation or pursue graduate study in fields as diverse as communications, business, instructional design, information design, education, and science and healthcare writing.

Various opportunities for writers to gain professional experience are available through campus publications, department-sponsored internships for academic credit, and writing-related employment on and off campus. TW students have the option of doing internships for academic credit during their junior or senior year and are encouraged to pursue a series of internships throughout their 4 years and during their summers.

All TW students are required to enroll in the English Department's 3-unit course, Professional Seminar (76-300), which meets once a week during the fall term and provides majors with the opportunity to meet and network with practicing professionals in a range of communications fields.

The Technical Communication (TC) Track

The Technical Communication track (TC) prepares students for careers in the rapidly changing areas of software and digital media. Students learn the fundamentals of visual, verbal, and on-line communication as well as the technical skills needed to design, communicate, and evaluate complex communication systems and to manage the interdisciplinary teams needed to develop them. Students become fluent in both print-based and electronic media across a variety of information genres and learn to design information for a range of specialist and non-expert audiences. The TW/TC major can be pursued as a primary major within Dietrich College or as an additional major for students in other Colleges with an interest in combining their specialized subject matter knowledge with strong writing and communications skills. Graduates of this track are likely to follow in the footsteps of previous TW students from Carnegie Mellon who are currently employed as web designers, information specialists, technical writers, and information consultants in a range of technology and communication-based organizations including Salesforce, IBM, Oracle, Microsoft, Apple, and HP Vertica.

The Scientific and Medical Communication (SMC) Track

The Scientific and Medical Communication track (SMC) is designed for students who seek careers that focus on communication and information design problems in health, science, and medicine. It should appeal to students with interests in the health care professions, science and public policy, patient education, scientific journalism and related fields. Like the TC track, the SMC track is designed to provide both the technical and the communication skills needed to analyze and solve complex communication problems. Students learn the fundamentals of visual, verbal, and on-line communication as well as the technical skills needed to design, communicate, and evaluate complex information systems and to manage the interdisciplinary teams needed to develop them. Students become fluent in both print-based and electronic media across a variety of information genres and learn to design information for a range of specialist and non-expert audiences The TW/SMC major can be pursued as a primary major within Dietrich College or as a secondary major for students in other Colleges, such as MCS, with an interest in science or medicine.

Curriculum

All Technical Writing majors must satisfy the Dietrich College requirements for the B.S. degree, and a set of 3 to 4 prerequisite courses in calculus, statistics, and computer science. All prerequisites should be completed by the beginning of the fall semester, junior year. Prerequisites may double count toward Dietrich College Requirements or requirements for other majors or minors.

Mathematics Prerequisite (1 course, 10 units):

Complete one of the following:		Units
21-111	Calculus I	10
21-112	Calculus II	10
21-120	Differential and Integral Calculus	10
21-127	Concepts of Mathematics	12

Statistics Prerequisite (1 course, 9 units):

36-200	Reasoning with Data	9

Computer Science Prerequisites (1 - 2 courses*, 10 - 22 units):

Students in the Technical Communication track must complete two required Computer Science courses:		Units
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12

Students in the Scientific and Medical Communication track complete one required Computer Science course:		Units
15-110	Principles of Computing	10

15-110 Principles of Computing is designed for students with little or no prior programming experience and is appropriate for students in both the SMC and TC tracks. 15-112 Fundamentals of Programming and Computer Science prepares students in the TC track for all other advanced Computer Science courses.

Beyond these prerequisites, students in both TC and SMC tracks take a common set of 5 TW Core Requirements in writing, communication, and information design. To complement these foundations courses, TW students take a set of 3 Theory/Specialization courses specific to either TC or SMC. In addition, students in the SMC track take a series of 3 courses in the natural sciences or engineering relevant to their areas of interest, while TC students take 3 electives in management, technology, and social issues.

DEPARTMENTAL CORE REQUIREMENT (1 COURSE, 9 UNITS):

Introductory Genre Writing Course		
76-260	Introduction to Writing Fiction	9
76-261	Intro to Writing Creative Nonfiction	9
76-265	Introduction to Writing Poetry	9
76-269	Introduction to Screenwriting	9

TW Core Requirements (5 courses, 45 units):

76-271	Introduction to Professional and Technical Writing	9
76-300	Professional Seminar	3
76-390	Style	9
76-391	Document & Information Design *	9
76-487	Information Architecture & Content Strategy	9
76-488	Information Architecture & Content Strategy Lab	3

* prerequisite = 76-271 Introduction to Professional and Technical Writing
**prerequisite = 76-271 Introduction to Professional and Technical Writing + 76-391 Document & Information Design

Theory/Specialization Courses (3 courses, 27 units):

Complete 3 courses to deepen your area of specialty and complement your chosen track (TC or SMC) in the major. One must be chosen from among courses designated as Recommended Options for TW majors. Theory/Specialization courses, including those marked as Recommended Options, are advertised by the English Department on a semester-by-semester basis. TW students should select courses in consultation with their academic advisor.

Recommended courses include but are not limited to the following:		Units
76-319	Environmental Rhetoric	9
76-395	Science Writing	9
76-425	Rhetoric, Science, and the Public Sphere	9
76-474	Software Documentation	9
76-476	Rhetoric of Science	9
76-481	Introduction to Multimedia Design *	12
76-491	Rhetorical Analysis	9
76-494	Healthcare Communications	9

Additional Options include but are not limited to the following:		Units
76-301	Internship	Var.
76-302	Communication Support Tutoring Practicum	6
76-318	Communicating in the Global Marketplace	9
76-319	Environmental Rhetoric	9
76-325	Intertextuality	9
76-351	Rhetorical Invention	9
76-360	Literary Journalism Workshop	9
76-372	News Writing	9
76-389	Rhetorical Grammar	9
76-395	Science Writing	9
76-425	Rhetoric, Science, and the Public Sphere	9
76-474	Software Documentation	9
76-475	Law, Performance, and Identity	9
76-476	Rhetoric of Science	9
76-481	Introduction to Multimedia Design	12
76-484	Discourse Analysis	9
39-605	Engineering Design Projects	12

Electives (3 courses, 27 units):

TW majors take 3 courses outside of English to deepen their area of specialty in their track. Typically, students in the Technical Communication (TC) track select courses that focus on management, technology, and social issues. Students in the Science and Medical Communication (SMC) track select courses in the natural sciences, engineering, statistics or (for example) healthcare-related courses in the Heinz College. (https://www.heinz.cmu.edu/) Students should work with their academic advisor and the Program Director to select courses that are meaningful for their track.

Double Counting

Students may double count up to two courses with other programs outside of the Department of English. **NOTE:** courses being used for the Dietrich General Education requirements do not have a double-counting limit. Also, the *Mathematics* and *Computer Science* prerequisite requirement courses for the Technical Writing major do not have a double-counting limit, nor do the Electives required for each specific track (TC track or SMC track).

Transfer Courses

Students may transfer up to two advisor-approved courses from other non-CMU programs/institutions toward the primary or additional major in Creative Writing or the BHA in Technical Writing, with the exception of the *Introductory Genre Writing Course* and *Technical Writing Core Requirement Courses*. If the two-course maximum is met, other related transfer courses will be considered for general education requirements and free electives for graduation. Please see the Dietrich College Advanced Standing and Transfer

Credit Policy (https://www.cmu.edu/dietrich/advisory-center/scheduling-classes/ap-and-transfer-credit.html) for more information.

Recommended Curriculum Pathway: B.S. in Technical Writing

This plan is the recommended pathway for completing the B.S. in Technical Writing in four years. While it is not required for students to follow this pathway precisely, it is highly recommended for students to do so, and we recommend students begin the major's courses as early as possible. Students in Dietrich College may declare their primary major as early as February 1. Students who have not declared their major in the Department of English may still take courses with us.

Students may also view the four-year plan (also known as a Pathway) for the B.S. in Technical Writing via the Stellic Degree Audit Application (https://www.cmu.edu/es/stellic/).

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
GEN ED: Foundations: Communication Course	GEN ED: Foundations Data Analysis Course	GEN ED: Foundations Scientific Inquiry Course	GEN ED: Foundations Intercultural & Global Inquiry Course
GEN ED: Disciplinary Perspectives: Humanities Course	GEN ED: Disciplinary Perspectives: Social Sciences Course	15-112 Fundamentals of Programming and Computer Science (for TC Track students) OR Free Elective (for SMC Track students)	GEN ED: Equity and Justice Course
GEN ED: Grand Challenge Seminar Course	15-110 Principles of Computing	76-26x Introductory Genre Writing Course (Fiction, Creative Nonfiction, Poetry, or Screenwriting)	76-390 Style
Mathematics Prerequisite Course for TW Major	76-271 Introduction to Professional and Technical Writing	76-300 Professional Seminar	Technical Communication Elective #1 (TC Track students) OR Free Elective (SMC Track students)
Free Elective	Free Elective	Free Elective	Free Elective

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
GEN ED: Foundations: Contextual Thinking	Open for course exploration, requirements for other majors/minors, study abroad, etc.	GEN ED: Disciplinary Perspectives: Additional Course (Business, Design, Engineering)	Optional GEN ED: Senior Capstone
GEN ED: Disciplinary Perspectives: The Arts Course	Open for course exploration, requirements for other majors/minors, study abroad, etc.	Theory and Specialization Course #1 (from Recommended List)	Theory and Specialization Course #3
76-391 Document & Information Design	Open for course exploration, requirements for other majors/minors, study abroad, etc.	Theory and Specialization Course #2	Free Elective (TC Track students) OR Natural Science & Engineering Elective #3 (SMC Track students)
Technical Communication Elective #2 (TC Track students) OR Natural Science & Engineering Elective #1 (SMC Track students)	Open for course exploration, requirements for other majors/minors, study abroad, etc.	Technical Communication Elective #3 (TC Track students) OR Natural Science & Engineering Eletive #2 (SMC Track students)	76-487 Information Architecture & Content Strategy
Free Elective	Open for course exploration, requirements for other majors/minors, study abroad, etc.	Free Elective	76-488 Information Architecture & Content Strategy Lab
			Free Elective

*These courses must be taken in the sequence indicated. 76-271 is offered all semesters and therefore can be taken fall or spring of sophomore year. 76-271 is a prerequisite for 76-391, and 76-271 + 76-391 are the prerequisites for 76-487 and 76-488. 76-391 is typically only offered in the fall semesters, and 76-487 and 76-488 are typically only offered in spring semesters.

Completing an Additional Major in English

For Students with a Primary Major in the English Department

Students with a primary major in the English Department who have interests that include more than one of the department's majors have the option of completing an additional major within the department. Students may combine any of the departmental majors with one another, with the exception of Professional Writing and Technical Writing. Students may not combine these two majors because so many of the courses overlap.

Students with a primary major in the English Department and one or more additional majors in the English Department must fulfill the Core Requirements for each of those majors. The Survey of Forms requirement, common to all 5 majors, needs to be taken only once, with the exception of Creative Writing, which requires two Survey of Forms courses. For the English Department majors that require English Electives, students must complete the number of English Electives required by the major with the higher number of Electives. For example, a student with a primary major in Creative Writing and an additional major in Professional Writing would take 4 English Electives, as Creative Writing requires 4 English Electives, and Professional Writing requires only 3 English Electives.

Because students are only required to take a minimum of one Introductory Genre Writing course, with the exception of Creative Writing, which requires two Introductory Genre Writing courses, as well as the number of English Electives that is greater between the primary and additional major(s), students can generally add an additional major within the English Department by completing 6 to 9 additional courses.

Because sequencing of courses can become an issue when doing multiple majors, students are strongly advised to consult closely with the English Department academic advisor about the sequence of their courses. The English Department academic advisor can also provide students with documents that clearly outline the requirements for additional majors based on their primary majors within the Department.

For Students with a Primary Major Outside of the English Department

Students in other departments who wish to complete an additional major in the English Department should contact the English Department's academic advisor. Additional majors in the five English programs are required to complete all requirements for the chosen major. The English Department will allow a maximum of two courses from the additional major to double count with the primary major requirements. (The types of courses that apply to this policy are predetermined by the Department of English. See the English Academic Advisor for more details.) The only exceptions to this rule are the Technical Communication Electives for the *Technical Communication* concentration in the Technical Writing major and the Natural Science and Engineering Electives for the *Science & Medical Communication* concentration in the Technical Writing major. All of those electives may double count with programs outside of the English Department. In planning schedules for an additional major, it is critically important that students consult with academic advisors in both departments in which they are majoring to be sure that all requirements for graduation can be met.

Transfer Courses for Additional Majors

The transfer course policy for additional majors is the same of that for primary majors. Please see the Transfer Courses section for the degree that aligns with your additional major. For example: If you have an additional major in Creative Writing, you will consult the Transfer Courses section for the B.A. in Creative Writing.

Minor in English

The English Department also offers minors in **Creative Writing, Humanities Analytics, Literature & Culture, Professional Writing,** and **Technical Writing**. We also house two Dietrich College interdisciplinary minors in **Film and Media Studies** and **Gender Studies** **(p. 541).** All of these minors are available to all undergraduate students, including English majors.

Double Counting

Students who have a minor in English *as well as* a primary and/or an additional major in English may not double count any English courses with that minor. (Please see the separate double counting rules for the interdisciplinary minors in Film and Media Studies and Gender Studies.) Otherwise, up to two courses from the minor may double count with programs outside of the English Department. Courses that meet the various requirements are advertised on a semester-by-semester basis. Full descriptions are available each semester on the Department's Courses (https://www.cmu.edu/dietrich/english/courses/) web page.

Transfer Courses

Students may transfer in a maximum of one advisor-approved course from an institution outside of Carnegie Mellon University, **with the exception of the following courses**, to count toward a minor:

- Creative Writing: 76-26x Introductory Genre Writing Course
- Humanities Analytics: 76-275 Introduction to Critical Writing and 76-380 Methods in Humanities Analytics
- Film & Visual Media: 76-239 Introduction to Film Studies and 76-310 Advanced Studies in Film and Media
- Literature & Culture: 76-26x Introductory Genre Writing Course and 76-275 Introduction to Critical Writing
- Professional Writing: *Required Intro Course* and the *Core Writing Courses*
- Technical Writing: *Required Intro Course* and the *Core Writing Courses*

Courses that meet the various requirements are advertised on a semester-by-semester basis. Full descriptions are available each semester on the Department's Courses (https://www.cmu.edu/dietrich/english/courses/) web page.

Creative Writing Minor

Complete 6 courses and a minimum of 54 units, which includes First-Year Writing.

Course		Units
First-Year Writing *		9
One Introductory Genre Writing Course †		9
76-xxx	Two 300/400 level Fiction, Poetry, and/or Screenwriting Workshop Classes	18
76-3xx	One Reading in Forms Course	9
76-2xx	One 200-level or above English Elective	9

* Course options include 76-101, 76-102, [76-106 and 76-107], [76-106 and 76-108], or [76-107 and 76-108].

\+ A student must earn a grade of A or B in the Introductory Genre Writing course in order to be eligible to enroll in a workshop of that same genre. A student who earns a grade of C in an Introductory Genre Writing course may enroll in a related workshop only with the permission of his/her/their workshop professor. A student who earns a D or R in an Introductory Genre Writing course may not take a workshop in that same genre.

† Course options include 76-260, 76-261, 76-265, and 76-269.

Humanities Analytics Minor

Tech CEOs and data scientists are increasingly calling for employees with more exposure to the humanities.

At the same time, the human experience that is traditionally at the core of a humanities education is being dramatically transformed by the emergence of big data, digital platforms, computational thinking, and digital connectivity.

Spurred by such developments, the minor in Humanities Analytics (HumAn) trains students in the processes involved in analyzing, digitizing, questioning, quantifying, and visualizing different types of humanities and cultural phenomena, such as printed books, fan fiction, manuscripts, historical records, art, music, and film.

The minor is open to students across multiple colleges and degree programs and enriches their education in distinct ways that complement their primary majors. For example, students with a primary major in a humanities or social science department will learn the foundational methods used in the computational analysis of text. Students with a primary major in a non-humanities field will use technology as a lens into cultural history and will develop skills for making humanities knowledge visible and appealing. The minor bridges divides not only between the "digital/technological" and the "humanistic," but also between the qualitative and quantitative, between theory and application, and between critiquing and making.

HumAn prepares students for careers in:

- Technology
- Data Science
- Data Journalism
- Cultural Commentary
- Natural Language Processing
- Professional Writing
- Publishing
- Museums
- Libraries
- Academia

Curriculum

Required Courses — 6 courses, 54 units minimum

Required Courses		Units
76-275	Introduction to Critical Writing	9
76-380	Methods in Humanities Analytics	9

Two core courses from the following list:		Units
76-314	Data Stories	9
76-388	Coding for Humanists	9
76-425	Rhetoric, Science, and the Public Sphere	9
76-429	Introduction to Digital Humanities	9
88-275	Bubbles: Data Science for Human Minds	9
88-300	Programming and Data Analysis for Social Scientists	9

Electives — 2 courses, 15-24 units

Choose two courses from the following categories. One course must come from List A, and one from List B. Additional courses not on List A or List B may also be approved as electives; please speak with the English Department academic advisor for more information.

List A

Course Number & Title		Units
05-391	Designing Human Centered Software	12
05-434/11-344	Machine Learning in Practice	12
11-411	Natural Language Processing	12
11-441/741	Machine Learning with Graphs [1]	9
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
16-223	IDeATe Portal: Creative Kinetic Systems	10
16-385	Computer Vision	12
17-340	Green Computing	9
17-450	Crafting Software	12
17-562	Law of Computer Technology	9
18-090	Twisted Signals: Multimedia Processing for the Arts	10
36-202	Methods for Statistics & Data Science	9
36-204	Discovering the Data Universe	3
36-226	Introduction to Statistical Inference	9
36-311	Statistical Analysis of Networks	9
36-315	Statistical Graphics and Visualization [2]	9
36-350	Statistical Computing [2]	9
36-462	Special Topics: Statistical Machine Learning	9
48-095	Spatial Concepts for Non-Architecture Majors	Var.
48-120	Digital Media I	6
51-229	Digital Photographic Imaging	9
53-451	Research Issues in Game Development: Designing for XR	12
60/62-142	Digital Photography I	10
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis	10

[1] Course is very mathematical and is therefore appropriate only to students with such a preparation.

[2] This course has prerequisites.

List B

Course Number & Title		Units
76-210	Banned Books	9
76-245	Shakespeare: Tragedies & Histories	9
76-247	Shakespeare: Comedies and Romances	9
76-325	Intertextuality	9
76-373	Argument	9
76-385	Introduction to Discourse Analysis	9
76-476	Rhetoric of Science	9
76-491	Rhetorical Analysis	9
79-200	Introduction to Historical Research & Writing	9
79-234	Technology and Society	9
80-180	Nature of Language: An Introduction to Linguistics	9
80-280	Linguistic Analysis	9
80-381	Meaning in Language	9
80-383	Language in Use	9
82-282	Interpreting Global Texts & Cultures	Var.
82-283	Language Diversity & Cultural Identity	9
82-383	Second Language Acquisition: Theories and Research	9
82-480	Translation Technologies	9

Literature & Culture Minor

Complete 6 courses and a minimum of 54 units, including First-Year Writing as a prerequisite.

Curriculum

Required Courses 6 courses, 54 units

Two Introductory Courses		Units
76-275	Introduction to Critical Writing	9
76-26x	Introductory Genre Writing Course (Fiction, Creative Nonfiction, Poetry, or Screenwriting)	9
		18

200-Level Literature & Culture Courses (2 courses, 18 units)

One course must cover the period of 1830 or before. For example, Course options include but are not limited to the following:

Courses for 1830 or Before		Units
76-203	Literature & Culture in the 18th Century	9
76-230	Literature & Culture in the 19th Century	9
76-233	Literature and Culture in the Renaissance	9
76-245	Shakespeare: Tragedies & Histories	9
76-247	Shakespeare: Comedies and Romances	9

Courses include but are not limited to:		Units
76-203	Literature & Culture in the 18th Century	9
76-207	Special Topics in Literature & Culture	9
76-210	Banned Books	9
76-217	Literature & Culture of the 20th and 21st Century	9
76-221	Books You Should Have Read By Now	9
76-230	Literature & Culture in the 19th Century	9
76-232	Introduction to Black Literature	9
76-233	Literature and Culture in the Renaissance	9
76-239	Introduction to Film Studies	9
76-290	Literature & Culture in the 20th Century	9
76-241	Introduction to Gender Studies	9
76-245	Shakespeare: Tragedies & Histories (if not taken for pre-1830 requirement)	9
76-247	Shakespeare: Comedies and Romances (if not taken for pre-1830 requirement)	9
76-259	Film History	9
76-287	Sex & Texts	9

300- or 400-Level Literature & Culture or Theory Courses (2 Courses, 18 units)

Course options include but are not limited to the following:

Courses include but are not limited to:		Units
76-310	Advanced Studies in Film and Media	9
76-313	Creative Visual Storytelling in Film Production	9
76-314	Data Stories	9
76-315	19th Century American Literature	9
76-317	Contemporary American Fiction	9
76-326	Contemporary Global Literature	9
76-329	Performing Race in Early Modernity	9
76-337	Intersectional Feminism	9
76-339	Topics in Film and Media	9
76-343	Rise of the American Novel	9
76-350	Critical Theories about Literature	9
76-353	Transnational Feminisms: Fiction and Film	9
76-367	Fact Into Film: Translating History into Cinema	9
76-429	Introduction to Digital Humanities	9
76-439	Seminar in Film and Media Studies	9
76-440	Postcolonial Theory: Diaspora and Transnationalism	9
76-445	Milton	9
76-448	Shakespeare on Film	9
76-452	Generations and Culture	9
76-453	Literature of Empire	9
76-454	Rise of the Blockbuster	9
76-467	Crime Fiction and Film	9

Professional Writing Minor

Complete 6 courses and a minimum of 54 units.

Required Intro Course		Units
76-270	Writing for the Professions	9
or 76-271	Introduction to Professional and Technical Writing	

Two 200- or 300-Level Core Writing Courses		Units
76-26x	Introductory Genre Writing Course (Fiction, Creative Nonfiction, Poetry, or Screenwriting)	9
76-373	Argument	9
76-389	Rhetorical Grammar	9
76-390	Style	9

Two 300- or 400-Level Writing Courses (18 units minimum)		Units
76-306	Editing and Publishing (requires instructor permission)	Var.
76-308	Literary Journal Publishing	Var.
76-314	Data Stories	9
76-318	Communicating in the Global Marketplace	9
76-325	Intertextuality	9
76-351	Rhetorical Invention	9
76-354	Watchdog Journalism	9
76-360	Literary Journalism Workshop	9
76-372	News Writing	9
76-384	Race, Nation, and the Enemy	9
76-388	Coding for Humanists	9
76-391	Document & Information Design	9
76-395	Science Writing	9
76-397	Instructional Text Design	9
76-415	Mediated Power and Propaganda	9
76-418	Rhetoric and the Body	9
76-425	Rhetoric, Science, and the Public Sphere	9
76-457	Rhetorical Invention	9
76-474	Software Documentation	9
76-475	Law, Performance, and Identity	9
76-476	Rhetoric of Science	9
76-481	Introduction to Multimedia Design	12
76-484	Discourse Analysis	9
76-487	Information Architecture & Content Strategy	9

76-488	Information Architecture & Content Strategy Lab	3
76-492	Rhetoric of Public Policy	9
76-494	Healthcare Communications	9
76-496	Research Methods in Rhetoric & Writing Studies (requires instructor permission)	9

One 200-Level or Above English Elective	Units
Students may choose from the Department's listings. Please contact the academic advisor for more information.	9

Technical Writing Minor

Complete 6 courses and a minimum of 54 units.

Required Intro Course		Units
76-270	Writing for the Professions	9
or 76-271	Introduction to Professional and Technical Writing	

Two 200- or 300-Level Core Writing Courses		Units
76-373	Argument	9
76-389	Rhetorical Grammar	9
76-390	Style	9
76-391	Document & Information Design	9

Two 300- or 400-Level Theory/Specialization Courses (18 units minimum)		Units
76-301	Internship (requires department approval)	Var.
76-302	Communication Support Tutoring Practicum	Var.
76-314	Data Stories	9
76-318	Communicating in the Global Marketplace	9
76-380	Methods in Humanities Analytics	9
76-395	Science Writing	9
76-397	Instructional Text Design	9
76-474	Software Documentation	9
76-476	Rhetoric of Science	9
76-481	Introduction to Multimedia Design	12
76-483	Research Methods in Technical & Professional Communication	9
76-487	Information Architecture & Content Strategy	9
76-488	Information Architecture & Content Strategy Lab	3
76-496	Research Methods in Rhetoric & Writing Studies (requires instructor approval)	9

Additional 300- or 400-Level Theory/Specialization Course		Units
In addition to any of the courses above that have not already been taken, courses include but are not limited to:		
76-306	Editing and Publishing (requires instructor approval)	Var.
76-318	Communicating in the Global Marketplace	9
76-325	Intertextuality	9
76-354	Watchdog Journalism	9
76-360	Literary Journalism Workshop	9
76-372	News Writing	9
76-384	Race, Nation, and the Enemy	9
76-389	Rhetorical Grammar	9
76-415	Mediated Power and Propaganda	9
76-418	Rhetoric and the Body	9
76-457	Rhetorical Invention	9
76-464	Creative Nonfiction Workshop	9
76-475	Law, Performance, and Identity	9
76-492	Rhetoric of Public Policy	9
76-494	Healthcare Communications	9

Senior Honors Thesis

Seniors in all five majors in the Department of English who meet the necessary requirements are invited by the College of Humanities and Social Sciences (Dietrich College) to propose and complete a Senior Honors Thesis during their final year of study. The thesis may focus on research and/or original production in any of the areas offered as a major within the Department. To qualify for the Dietrich College Honors Program, students must have a cumulative Quality Point Average (QPA) of at least 3.50 in their major and 3.25 overall at the end of their junior year and be invited by Dietrich College to participate. Students then choose a thesis advisor within the Department and propose and get approval from Dietrich College for a Senior Honors Thesis. The Honors Thesis is completed over the two semesters of the senior year (9 units each semester) under the direction of the chosen advisor. By successfully completing the thesis, students earn 18 units of credit and qualify for graduation with “College Honors.”

Creative Writing majors participating in the Senior Honors Thesis program who thesis is directly related to their Creative Writing major may petition to have one semester of their thesis work count as one of their Workshop course requirements.

Internships for Credit

Qualified students in all five of the Department’s degree programs have the option of doing a professional internships for academic credit during. These opportunities help students explore possible program-related careers as well as gain workplace experience. Our students have interned in a wide variety of communications-related positions including placements at local radio, television, and print publications; museums, theaters, and cultural organizations; non-profit and public service organizations; public relations, advertising, and marketing firms; software and technology companies; media organizations; and hospitals and healthcare communication organizations.

Students majoring in Creative Writing, Film & Visual Media, Literature & Culture, Professional Writing, or Technical Writing can count one 9.0- or 12.0-unit enrollment in 76-301 Internship toward requirements in their major.

- In Creative Writing these 9.0- to 12.0 units can count toward the fulfillment of an English elective.
- In Film & Visual Media, these 9.0- to 12.0 units can count toward a production elective.
- In Professional Writing, these 9.0- to 12.0 units can count towards the fulfillment of an English elective or an advanced writing course.
- In Technical Writing, these 9.0- to 12.0 units can count towards the fulfillment of a technical communication elective.

Students minoring in the Department of English who wish to earn credit for an internship related to their minor should contact the Director of Undergraduate Studies, Professor Stephanie Larson, at srlarson@andrew.cmu.edu.

The Dietrich College policy allows up to 27.0 units of internship credit to count toward the overall 360.0 units students need to complete their degrees. For non-Dietrich primary majors, please consult your home college’s policy.

Students are permitted to earn pay at the internship for which they are also earning credit.

To learn more about internships for credit in the Department of English, please see our Internship for Credit Policies and Procedures (https://docs.google.com/document/d/1nNsenF4qCII78D-V2ULqKWwD_o45Ii5ZDAc9v3ByDbo/edit/?usp=sharing).

The Accelerated MA in Professional Writing: MAPW 4+1

The Master of Arts in Professional Writing (MAPW) 4+1 is an accelerated masters program under which Carnegie Mellon students (usually majors or minors in the English department or BHA or BHS students with relevant coursework) can qualify to complete the M.A. in Professional Writing in 2 semesters and a required full-time internship instead of the usual 3 semesters and a summer internship. Most 4+1 students complete their internship requirement during the summer after their graduation.

Students apply for admissions during their senior year (the GRE is not required) and, following admission and evaluation of their transcripts, may receive credit for up to four courses, or one full semester of work, toward their M.A. requirements. The degree provides the advantages of an M.A. degree in an accelerated time frame, features intensive work in writing and visual design for both print and new media, and prepares students for a range of communications careers.

The coursework and career options most commonly pursued by students in the degree include:

- Technical Writing
- Science and Healthcare Writing
- UX Writing/Content Design
- Information Architecture

- Public & Media Relations / Corporate Communications
- Nonprofit & Policy Communication
- Editing and Publishing

Students interested in applying to the 4+1 program should consult the Director of the MAPW program, Professor Suguru Ishizaki at suguru@cmu.edu, early in their junior year for further details and advice on shaping undergraduate coursework to qualify for this option.

Faculty

MARIAN AGUIAR, Associate Professor of English – Ph.D., University of Massachusetts;

JANE BERNSTEIN, Professor of English – M.F.A., Columbia University;

DAVID BROWN, Associate Teaching Professor of English, Associate Director of First-Year Writing for Research and Assessment – Ph.D., Lancaster University;

DOUG COULSON, Associate Professor of English – Ph.D., The University of Texas at Austin;

JAMES DANIELS, Professor Emeritus of Creative Writing – M.F.A., Bowling Green State University;

SHARON DILWORTH, Associate Professor of English – M.F.A., University of Michigan;

JASON ENGLAND, Assistant Professor of English – M.F.A., Iowa Writers' Workshop;

LINDA FLOWER, Professor Emerita of English – Ph.D., Rutgers University;

KEVIN GONZÁLEZ, Assistant Professor of English – M.F.A., Iowa Writers' Workshop;

SUSAN HAGAN, Assistant Teaching Professor, Liberal & Social Sciences, Carnegie Mellon University-Qatar – Ph.D., Carnegie Mellon University;

PAUL HOPPER, Paul Mellon Distinguished Professor Emeritus of the Humanities, Rhetoric and Linguistics – Ph.D., University of Texas;

SARAH HAE-IN IDZIK, Assistant Professor of English – Ph.D., Northwestern University;

SUGURU ISHIZAKI, Professor of English, Director of Undergraduate Professional & Technical Writing Programs and Graduate Professional Writing Program (MAPW) – Ph.D., Massachusetts Institute of Technology;

BARBARA JOHNSTONE, Professor Emerita of English and Linguistics – Ph.D., University of Michigan;

DAVID S. KAUFER, Mellon Distinguished Professor Emeritus of English – Ph.D., University of Wisconsin;

ALAN KENNEDY, Professor Emeritus of English – Ph.D., University of Edinburgh;

JON KLANCHER, Professor Emeritus of English – Ph.D., University of California at Los Angeles;

PEGGY KNAPP, Professor Emerita of English – Ph.D., University of Pittsburgh;

STEPHANIE LARSON, Assistant Professor of English and Director Undergraduate Studies – Ph.D., University of Wisconsin-Madison;

JOAN LUBIN, Assistant Professor of English – Ph.D., University of Pennsylvania;

ATESEDE MAKONNEN, Assistant Professor of English – Ph.D., The Johns Hopkins University;

JANE MCCAFFERTY, Professor of English – M.F.A., University of Pittsburgh;

TOM MITCHELL, Assistant Teaching Professor, Liberal & Social Sciences; Carnegie Mellon University-Qatar – Ph.D., Carnegie Mellon University;

CHRISTINE NEUWIRTH, Professor Emerita of English and Human Computer Interaction – Ph.D., Carnegie Mellon University;

KATHY M. NEWMAN, Associate Professor of English and Director of Graduate Studies – Ph.D., Yale University;

JOHN J. ODDO, Associate Professor of English – Ph.D., Kent State University;

SILVIA PESSOA, Associate Teaching Professor, Liberal & Social Sciences, Carnegie Mellon University-Qatar – Ph.D., Carnegie Mellon University;

NUPOOR RANADE, Assistant Professor of English – Ph.D., North Carolina State University;

CAMILLE RANKINE, Assistant Professor of English – M.F.A., Columbia University;

DUDLEY REYNOLDS, Teaching Professor, Liberal & Social Sciences, Carnegie Mellon University-Qatar – Ph.D., Indiana University, Bloomington;

ANDREEA DECIU RITIVOI, William S. Dietrich Professor of English, Department Head – Ph.D., University of Minnesota;

KAREN SCHNAKENBERG, Teaching Professor Emerita of English – Ph.D., Carnegie Mellon University;

LAUREN SHAPIRO, Associate Professor of English and Director of Creative Writing Program – M.F.A., Iowa Writers' Workshop;

DAVID R. SHUMWAY, Professor of English – Ph.D., Indiana University;

KRISTINA STRAUB, Professor Emerita of English – Ph.D., Emory University;

CHRISTOPHER WARREN, Professor of English and Associate Department Head with a Courtesy Appointment in History – D. Phil., University of Oxford;

MARIAM WASSIF, Assistant Professor of English – Ph.D., Cornell University;

DANIELLE WETZEL, Teaching Professor; Director of Writing & Communication Program – Ph.D., Carnegie Mellon University;

JEFFREY WILLIAMS, Professor of English – Ph.D., Stony Brook University;

STEPHEN WITTEK, Associate Professor of English and Director of Literary and Cultural Studies Program – Ph.D., McGill University;

JOANNA WOLFE, Teaching Professor of English – Ph.D., The University of Texas at Austin;

JAMES WYNN, Associate Professor of English, Director of Rhetoric Program – Ph.D., University of Maryland;

Special Faculty

MARIO CASTAGNARO, Special Faculty, Professional & Technical Writing

EMMA FRIES, Director, Arts Greenhouse

ROCHEL GASSON, Special Faculty, Writing & Communication

ANDREW GORDON, Special Faculty, Writing & Communication

ALAN HOUSER, Special Faculty, Professional & Technical Writing

SUZANNE MEYER, Special Faculty, Writing & Communication

KORRYN MOZISEK, Special Faculty, English

KAT MYERS, Special Faculty, Writing & Communication

JULIE PAL-AGRAWAL, Special Faculty, Writing & Communication

ROBYN ROWLEY, Special Faculty, Writing & Communication

JULIA SALEHZADEH, Special Faculty, Writing & Communication

ED SIMON, Special Faculty, English

BRIAN STASZEL, Special Faculty, Professional & Technical Writing

ISABELLE STROLLO, Special Faculty, Film & Visual Media

ANTHONY SWOFFORD, Special Faculty, Creative Writing

CHAD SZALKOWSKI-FERENCE, Special Faculty, Writing & Communication

STEVE TWEDT, Special Faculty, Professional & Technical Writing

RALPH VITUCCIO, Special Faculty, Film & Visual Media

Lecturer

KEELY AUSTIN, Visiting Lecturer, Departments of English and Languages, Cultures, & Applied Linguistics

JANINE CARLOCK, Lecturer, Writing & Communication

ANDREA COMISKEY, Lecturer, Writing & Communication

BARBARA GEORGE, Senior Lecturer, Writing & Communication

JEFFREY HINKELMAN, Senior Lecturer, Director of the Film & Visual Media Program, Director of Pre-College Program in Writing & Culture

ALAN KOHLER, Senior Lecturer, Writing & Communication

PETER ZARAGOZA MAYSHLE, Senior Lecturer, Writing & Communication

COURTNEY NOVOSAT, Senior Lecturer, Writing & Communication

JULIE PAL-AGRAWAL, Lecturer, Writing & Communication

JEREMY ROSSELOT-MERRITT, Senior Lecturer, Writing & Communication

SETH STRICKLAND, Lecturer, Writing & Communication

REBECCA WIGGINTON, Senior Lecturer, Writing & Communication

HEIDI WRIGHT, Senior Lecturer, Writing & Communication – Course Lead, ENG 76-100,

JUNGWAN YOON, Senior Lecturer, Writing & Communication

Department of English Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

76-050 Study Abroad

All Semesters
No course description provided.

76-100 Reading and Writing in an Academic Context

Fall and Spring: 9 units
Designed as an entry point for other first-year writing courses at Carnegie Mellon, 76100 is an academic reading and writing course for multilingual students which offers a space for learners to recognize and use the communicative strengths that are created by knowing two or more languages. Experiences in the course give students the opportunity to draw on multiple cultural and linguistic understandings and practices when analyzing and creating meaningful texts. The course emphasizes critical reading and research strategies for a variety of sources which become the basis for individually and collaborativelyproduced texts. The course introduces students to rhetorical choices within and across languages at the sentence, paragraph, and whole text or genre levels. Students will explore a variety of practices in academic writing (e.g., paraphrase, synthesis, counterargument and refutation, citation) as they relate to genre, audience, purpose, and other factors of a communicative situation. We discuss and practice explicit rhetorical and linguistic conventions for writing in academic English so that writers make choices to connect with readers in academic and professional discourse communities. Students who take this course identify as multilingual students who use English skillfully but perhaps with less comfort as they use another language. These students complete an online placement process that guides them through making their own informed course placement. Students may also skip the placement process and enroll directly into the course. For some students, 76100 is a prerequisite requirement for other first-year writing courses; therefore, students should check with their academic advisors regarding how 76100 fulfills their general education course requirements. All 76100 courses are structured by the learning objectives shared across sections of the course, but sections present different themes in their readings.

Course Website: https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/index.html (https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/)

76-101 Interpretation and Argument

All Semesters: 9 units
Interpretation and Argument, an inquiry-driven writing course, is one of a number of first-year writing course options available to students at Carnegie Mellon. A full-semester course experience, 76101 introduces students to foundational practices for reading, synthesizing and producing scholarly knowledge within an academic context. Within the course, students learn transferable, genre-based skills applicable to a variety of different fields. Students use a comparative genre analysis method for using models to complete new writing tasks, including an academic research proposal and a research article that contributes to an ongoing academic conversation. Faculty who teach 76-101 typically select a range of texts (e.g., scholarship, journalism, film) about an unresolved issue, so that students can identify relevant questions to frame their own research projects. Students should expect explicit, research-based instruction within the course, reflecting upon their writing processes, as well as planning, drafting and revising drafts. Because the course emphasizes authentic stakes and purposes for communicating with academic audiences, students will regularly share their work with their peers in oral and written forms within an interactive and collaborative classroom environment. Due to the limits of our schedule, we are unable to meet each student's individual preferences for course topics, but we do offer a wide variety from which to choose.

Course Website: https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/index.html (https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/)

76-102 Advanced First Year Writing: Special Topics

Fall and Spring: 9 units
76-102, Advanced First-Year Writing courses are designed for students who have demonstrated an understanding and practice of academic writing that most incoming freshmen have not, both in terms of mindful writing knowledge and experiential range. Because of the students' level of preparedness, the First-Year Writing Program provides intensive, advanced courses for students to work closely with senior faculty within the English department. Advanced courses assume that students have established strong reading and synthesizing skills, as well as a demonstrated interest in writing and communication, prior to entering Carnegie Mellon. The course topics shift each semester, but for every advanced first-year writing course, the core goals are to deepen students' rhetorical knowledge and production skills that align with the faculty member's specialty. Because the course emphasizes authentic stakes and purposes for communicating with academic audiences, students will regularly share their work with their peers in oral and written forms within an interactive and collaborative classroom environment. Students enroll through special invitation, after completing an application process. There are no prerequisites for the course.

Course Website: https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/index.html (https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/)

76-106 Writing about Literature, Art and Culture

Fall and Spring: 4.5 units
This mini or half-semester course (one of two minis students can choose to fulfill their FYW requirement) uses artistic, literary, and cultural texts (e.g., poetry, short story, lyrics, video clips) to introduce students to a variety of academic reading and writing practices that enable students to engage with texts and write about them with complexity and nuance. Within the course, we will discuss texts and evidence from multiple perspectives. We will examine how literary and cultural scholars write about texts (defined broadly), how they make claims, provide reasoning, and use textual support to argue for particular ways of seeing cultural objects. Throughout the semester, students will draw upon prior strategies and develop new ones for close reading and for critical analysis in order to produce their own thesis-driven arguments about why texts matter. We will consider and write about the extent to which these reading strategies are relevant for other kinds of reading and analysis by comparing texts from a variety of different disciplinary contexts. Because the course emphasizes authentic stakes and purposes for communicating with academic audiences, students will regularly share their work with their peers in oral and written forms within an interactive and collaborative classroom environment.

Course Website: https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/index.html (https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/)

76-107 Writing about Data

Fall and Spring: 4.5 units
This mini or half-semester course (one of two minis students can choose to fulfill their FYW requirement) focuses upon interpreting and making arguments using mainly numerical data but also qualitative data. We will look at research in a range of disciplines including psychology, education, medicine, engineering, and the sciences and note how writers select and analyze the data they collect. We will also examine what happens to this research when it is picked up by the popular media. Students will also practice collecting and analyzing their own data and reporting it to suit the needs of various stakeholders. There are two primary audiences for this section. Students in data-driven majors will find the section useful preparation for communicating in their disciplines. Students in other fields will learn how to critique and respond to the many ways that numbers shape our lives. This section presumes a basic ability to calculate averages, percentages, and ratios, but no advanced mathematical or statistical preparation. Instead, this section provides a fascinating look at how numbers and words intersect to create persuasive arguments in academic, professional, and popular contexts. Students will compare and analyze texts that make arguments with data, practice rhetorical strategies for synthesizing and representing data so that by the end of the class, students will apply these strategies to write an original data-driven research proposal. Because the course emphasizes authentic stakes and purposes for communicating with academic audiences, students will regularly share their work with their peers in oral and written forms within an interactive and collaborative classroom environment.

Course Website: https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/index.html (https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/)

76-108 Writing about Public Problems

Fall and Spring: 4.5 units
This mini or half-semester course (one of two minis students can choose to fulfill their FYW requirement) centers on introductory professional writing and offers students the opportunity to develop a proposal for change; students will examine a public problem of their choice, conduct primary and secondary research, and create a public-facing presentation. This course asks students to recognize that many problems we encounter in our communities require an invested stakeholder, like ourselves, to conduct a careful investigation of perspectives and constraints before proposing a feasible solution that considers diverse stakeholders' values and viewpoints. Students will learn how public problems are defined and argued in the proposal genre by reading a range of expert texts and analyzing a variety of sample proposals. Students will conduct various forms of social research (email, interview, survey, and/or observation) to gain perspective on a problem and develop a solution mindful of others' expertise and experience. Students will also synthesize relevant secondary research to rhetorically frame a proposal in ways that will compel their intended audience to take action. By the end of the course, students will write and present their own change proposal that identifies a community-based problem, proposes a thoughtfully-researched solution, and recommends a feasible plan for change in one of their own communities. Because the course emphasizes authentic stakes and purposes for communicating with professional and academic audiences, students will regularly share their work with their peers in oral and written forms within an interactive and collaborative classroom environment.

Course Website: https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/index.html (https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/)

76-203 Literature & Culture in the 18th Century

Fall: 9 units
Topics vary by semester. Fall 2022 This section will examine race, gender, and their intersections as points of entry into the major literary and cultural movements of the long eighteenth century, which continue to shape our present. From about 1660 to 1820, historical phenomena such as European empires, the Rights of Woman, and slavery and abolition coincided with changes in print and media culture to produce the rich literary productions we will study. Through reading and graded assignments such as short essays and oral presentations, students will learn methods for analyzing the formal features of literary texts (such as narrative structure and poetic rhythm) and how such texts respond to the pressures of history. Furthermore, students will develop their ability to think critically about race and gender, to argue persuasively, and to express ideas clearly. Examples of readings include Aphra Behn's Ooronoko, Jonathan Swift's "The Lady's Dressing Room," Jane Austen's Mansfield Park, Mary Prince's The History of Mary Prince, and William Wordsworth's "To Toussaint L'Ouverture."
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-204 Race, Ethnicity, Controversy

Intermittent: 9 units
Coverage of police violence. Condemnations of Critical Race Theory. Book bans. "Kung flu." In recent years, current issues around race have proliferated, and with them, complex layers of discourse and controversy. This course examines current issues around race through the twin lenses of rhetoric and ethnic studies, asking how power is expressed through rhetorics of race and controversy. What are the communicative practices involved in framing or responding to racial violence, prejudice, and controversy? How do these practices harness various cultural, political, and historical forces, and to what effect? How do these discourses contribute to racialization, and where, and how, are differential distributions of power being expressed? We will seek to understand discourses around these issues and the backgrounds of various debates, from policing and abolition, to recurring anti-Asian racism, to affirmative action debates, to transracial adoption. Students will learn to analyze discourses around race rhetorically, identify structures of power at work in these discourses, and produce a final paper analyzing the rhetorics of a current issue or controversy around race.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-206 Intro to Creative Writing

Intermittent: 9 units
In this course we will explore how stories work and why we tell them. Using screenplays, short fiction and personal essays, we will analyze how narratives function and how, upon reflection, narratives often function in very similar ways no matter what the genre. Storytelling has a shape. It dominates the way all stories are told and can be traced back in history to the very beginning of the recorded word. We will study traditional structure in screenplays and contemporary prose pieces, and consider stories from fairy tales to serialized television shows. These master texts will be used to guide the students as they write and develop their own stories.

76-207 Special Topics in Literature & Culture

Intermittent: 9 units
Topics very by semester and section. F24: Drama of Power and amp; Resistance - Writers throughout history have harnessed the power of the pen to give a voice to the silenced, center the marginalized, or dissent from systems of oppression. Politically charged poems, novels, and essays have changed the world. But of all genres, drama, one of the oldest art forms in the world, has been uniquely impactful in speaking truth to power and effecting social change. Dramatists from Ancient Greece until the modern age have harnessed the power of political commentary, resistance, and protest in their works for the stage. This class will examine politically engaged dramatic literature from a wide array of international and diverse voices ranging from protest plays of Ancient Greece (such as Aristophanes' Lysistrata), through Shakespearean histories that question the legitimacy of rulers and their power (King John or Coriolanus), to modern plays that force contemporary audiences to reconsider political polarization, war, and systemic inequalities in our society, such as Arthur Miller's The Crucible, the rock musical Hair, or Lynn Nottage's Ruined. We will look at the scripts, cultural contexts, and performance histories of such works, as well as interrogate what makes drama so unique as a genre and collaboratively develop reading strategies for plays. We will explore how realities of society such as systems of power, class, race, gender, and marginalization have been taken up by centuries of playwrights to comment on social and political systems. To supplement our reading, we will engage with multimedia adaptations and reimaginings of plays. In addition, our inquiry into how drama has impacted society will take a broad view of 'theater,' and look beyond the stage to examine how non-literary forms of activism and political response can also be seen as theatrical.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

Course Website: https://docs.google.com/spreadsheets/d/1U81b4BSF0aij6u_zYq39Uf7q2ZTiqqAQaOIJ9V2LhnA/edit?usp=sharing (https://docs.google.com/spreadsheets/d/1U81b4BSF0aij6u_zYq39Uf7q2ZTiqqAQaOIJ9V2LhnA/edit/?usp=sharing)

76-210 Banned Books

Fall: 9 units
Literature is powerful! Indeed, we're interested in books that are so controversial that people will shout, argue, and try to change laws in order to have a book removed from a curriculum, a school or public library, or a prison. At the same time we'll learn about how, in response, other people work extremely hard to defend books against removal and censorship. The term "banned books," can be a bit misleading in the US context; only in very rare cases does the US federal government get involved in trying to ban or censor a published work. Nonetheless, the US is a hot spot for those who seek to attack books, and for those who seek to defend them. In this course you will find that the actions of attackers and the actions of defenders are often mutually reinforcing. Every student in this course will contribute to a public facing website called The CMU Banned Books project. This website is used by journalists, scholars and activists around the world. This semester's books for reading and discussion include some of the most frequently banned and challenged books of the last five years, including The Handmaid's Tale, Gender Queer, The 1619 Project, and The Absolutely True Diary of a Part-Time Indian. Since 2020, organizations that track book banning tell us that the numbers of books banned and/or challenged are at an all-time high.

76-214 Understanding Cultural Complexities

Fall and Spring: 9 units
In today's society that explores Diversity, Equity, and Inclusion, one can ponder if Arab societies have made progress to achieve DEI towards minorities of religions (Muslims, Christians, Jews), sects (Sunni and Shi'a), ethnicities (Copts, Nubians, Kurds), Palestinians in Israel, homosexuals, and physical disabilities. This course aims to enrich students' understanding of the diversity of Arab countries and histories of intercommunal relations and conflict, explore the progress made in equating minorities to majorities, including them in various sectors, and granting them more rights. We will use readings, films, arts, and music, to engage with students in 4 Arab countries to further their learning.

76-216 Happily Ever After: Fantasies of Romance

Intermittent: 9 units
TBD

76-217 Literature & Culture of the 20th and 21st Century

Intermittent: 9 units
Spring 2022: If you're in college now, you're probably a member of "Generation Z." There are a number of studies of Generation Z and its disposition, habits, and interests. While we are familiar with factors that make up our identities and #8212;nationality, race, ethnicity, gender, sexuality, income, and abledness and #8212;one's generation is probably just as influential, and according to some sociologists, more important than those other factors. In this class we will look at portraits of American generations in fiction, from the Baby Boomers and Generation X through Millennials and Generation Z. We will also look at some of the sociology and see how it bears on the fiction. In addition, we might look back at past generations, such as the generation that came of age after World War I, the Lost Generation, which inspired writers such as F. Scott Fitzgerald, and the Beat Generation, which inspired Jack Kerouac. In more recent fiction, we might read fiction such as Coupland's Generation X, Lauren Groff's portrait of the sixties generation in Arcadia, or Ling Ma's portrait of Millennials in Severance. We will also look at film along with novels, possibly including The Big Chill, Reality Bites, and other movies.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-219 Law & Blame

Intermittent: 9 units
How do we use language to accuse and defend? How do we attribute responsibility to specific individuals or institutions and dispute such claims, either by debunking them or shifting the blame? What makes the stories we tell and the arguments we make about responsibility succeed or fail? What unintended consequences can they produce and for what groups? This course will examine these and related questions through the lens of legal cases in which individuals or institutions are accused of responsibility for harm, from vehicular accident cases to criminal trials. The study of these questions is not only valuable for understanding the legal process, participating in it, or writing about it, but the practice of attributing responsibility is common in many social and institutional contexts beyond law, even in daily conversation. The course explores fundamental questions about culture, ethics, and politics, including issues involving systematic and structural inequalities involving race, class, gender, sexual orientation, religion, and national origin, which are evident both in the legal cases studied and in the public imagination and controversy beyond the courtroom. The societal implications explored include inequitable constraints on freedom in criminal justice and economic inequalities perpetuated through civil lawsuits, as well as inequalities in cultural power and status in the ways some voices are recognized in the legal process and others are not. Drawing on readings from rhetoric, linguistics, and legal studies, as well as briefs, opening and closing arguments, direct and cross-examinations of witnesses, physical and documentary evidence, and judicial opinions from legal cases, we will examine the strategies advocates use to attribute responsibility, enhance equity, and manage such disputes.

76-220 Mystery: From Detective Fiction to True Crime

Intermittent: 9 units
Mystery fiction is one of the most enduring and popular literary genres, and there is no doubt that the current media landscape has hugely expanded the concept of the "armchair detective" to include podcasters, journalists, and true crime addicts. This course provides a better understanding of narrative and genre, as well as social norms around gender and race, by looking at the conventions of mystery fiction and true crime. What can these "formulaic" genres teach us about storytelling, character development, and narrative point of view? What do they reveal about a society's notions of justice and order? And how is textual analysis itself an act of detection? Texts may include podcasts, documentaries, and newstories; classic works by Wilkie Collins, Arthur Conan Doyle, and Walter Mosely; and contemporary works by Kiley Reid and Oyinkan Braithwaite
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-221 Books You Should Have Read By Now

Fall and Spring: 9 units
Topics vary by semester and section. F24: The United States prison system continues to grow, with nearly 2 million incarcerated people and over 6,000 prisons, jails, and detention centers nationwide. Its expansion disproportionately impacts impoverished communities, people of color, and LGBTQ+ people, as it is connected to a fraught history. Throughout this class, we will engage with novels, memoirs, letters, essays, and poetry written by incarcerated or formerly incarcerated people to understand the critiques they wage against the carceral state. We begin with early depictions of penitentiaries, then turn to political responses to imprisonment throughout the twentieth century, and close with literature about the contemporary carceral state. In studying representations of the US prison's development over time, we will ask: How do prison writers bear witness to and resist the prison-industrial complex? Readings might include works by Reginald Dwayne Betts, Jimmy Santiago Baca, Assata Shakur, Malcolm X, George Jackson, Jack Henry Abbot, and Chester Himes.

76-223 Contemporary Black Literature

Spring: 9 units
This course will take a transatlantic approach to what constitutes blackness as well as black literature and expression from the turn of the 20th century until the present. We will investigate the relationship between poetic forms and expressions of social and self-representation. However, this class will primarily focus on prose works (novels, memoirs and non-fiction essays) that span a multitude of genres from mystery to literary and science fiction. Authors include: W.E.B. Dubois, Zora Neale Hurston, James Baldwin, Zadie Smith, Claude McKay, Amiri Baraka, Franz Fanon, Marlon James, Edouard Glissant, Nnedi Okorafor, Merle Collins and Jamaica Kincaid to name a few.

76-230 Literature & Culture in the 19th Century

Intermittent: 9 units
Topics vary by semester. Fall 2023: Literature and amp; Social Change - From the French Revolution to the beginning of the twentieth century, literature began to play an explosive role in the forces of political transition and the struggle for social justice. This course studies novels, poetry and prose in relation to both political and industrial revolutions during the rise of empire and capitalism and the road to climate change. We will study apocalyptic novels like Mary Shelley's The Last Man and novels of empire like Jane Eyre and its retelling in Wide Sargasso Sea; poetry about living in revolutionary times by Wordsworth and Phillis Wheatley Peters; and anti-capitalist anti-slavery writing such as Ottobah Cugoano's "Thoughts and Sentiments on the Evil of Slavery."
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

76-232 Introduction to Black Literature

Intermittent: 9 units
This course will take a transatlantic approach to what constitutes blackness as well as black literature and expression from the turn of the 20th century until the present. We will investigate the way authors and artists use literature and other mediums of expression for social and self-representation. Our primary focus will be on prose works (novels, memoirs and non-fiction essays) that span a multitude of genres from mystery to literary and science fiction. There will also be sections of the course that focus other mediums such as visual art, comics, music, film and television. We will cover figures such as: Fredrick Douglass, W.E.B. Dubois, Zora Neale Hurston, Langston Hughes, Claude McKay, Amiri Baraka, Franz Fanon, Toni Morrison, Merle Collins, Kyle Baker, Kara Walker and Beyonce to name a few.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-233 Literature and Culture in the Renaissance

Intermittent: 9 units
The Renaissance was a time of world-shattering change brought about by innovation, exploration, colonization, religious upheaval, the emergence of capitalism, the print revolution, scientific discovery, and unprecedented flourishing in the creative arts. In England, the same years also ushered in a golden age for English literature, which grew into its own with the arrival of canonical authors such as Thomas More, William Shakespeare, Edmund Spenser, John Milton, and many others. This course will introduce students to literary and cultural studies by convening a survey of works from the English Renaissance alongside a selection of critical readings that will help to bring England's extraordinary literary output into connection with its equally fascinating cultural context. In addition to canonical works by authors such as Shakespeare and Milton, we will also study lesser-known works by brilliant female authors such as Elizabeth Carey and Margaret Cavendish, women who have been left out of the traditional canon, not for a lack of literary merit, but because of their gender. On a similar note, the course will also consider questions such as, "How can modern readers best navigate the ethical hazards presented by problematic, centuries-old artworks?" "To what extent can we hold such artworks responsible for ideas that violate contemporary values, or contemporary boundaries of appropriateness?" and "To what extent can one study and learn from such artworks without endorsing or perpetuating the objectionable ideas or opinions they represent?" As we read, write, and converse together, we will work toward a broad understanding of what the literature of the English Renaissance means in a 21st century context, and how it has helped to shape the culture of modernity.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

76-236 Major Fiction Then and Now

Intermittent: 9 units
We read newspapers for reports about what is happening in our world. But we also read fiction and #8212;novels and stories and #8212;that tell us about imaginary worlds. Sometimes they are very much like our world, sometimes different. In this course we'll read classic novels like Charles Dickens' Great Expectations or Dostoyevsky's Crime and Punishment up to contemporary ones like Station Eleven or Severance. We will consider how they represent the world, their use of literary forms, and how they lead us into their alterior world. We will also consider what they say about their culture and society. Do they make a statement about the world, or are they more for entertainment? This course is based on the Inside-Out Prison Exchange Program, and will be taught at SCI Somerset, a nearby prison. The course will include both "outside" students from CMU, as well as "inside" students at SCI Somerset. The course focuses on active participation and discussion between students. It runs from 2:30-5:10 on Friday afternoon. CMU students will travel together by bus, leaving our campus at 12:30 and returning by 6:30. To enroll, students in the course will submit a brief application and interview with faculty. The course is part of an exciting new initiative by CMU to bring education into America's prisons.

76-239 Introduction to Film Studies

Fall and Spring: 9 units
This course is an introduction to the history, technology, aesthetics, and ideology of film. Our main focus is the narrative fiction film, but we will also discuss documentaries, avant-garde work, and animation. The central organizing principle is historical, but there are a number of recurring thematic concerns. These include an examination of the basic principles of filmmaking, the development of film technology, the definition of film as both art and business, and the history of film as an object of critical and cultural study. The goals of this course are threefold. First, it will provide you with a solid grounding in the key issues and concepts of film studies. Second, it will expand your ability to knowledgeably critique individual cinematic works and their relationship to the larger culture. Lastly, it will provide you with experience in expressing your critiques in writing.

76-241 Introduction to Gender Studies

Fall and Spring: 9 units
Intersectional feminism. Structural oppression. Biological sex vs. gender roles. LGBTQIA+ rights. Consent. Masculinity. #metoo and gender-based violence. Sexual politics. Global feminism. This course offers students a scholarly introduction to these social and political issues through critical readings, literature and film. In this discussion-based class, students read and discuss contemporary gender studies that speaks to questions of identity, race, nation, sexuality, and disability. Critical readings include work by Audre Lorde, bell hooks, Judith Butler, Kimberl and #233; Crenshaw, Sara Ahmed, Eve Sedgewick, Raewyn Connell, Mari Matsuda, Mona Eltahawy, Rosemarie GarlandThomson, and Kate Bornstein. Fiction might include Toni Morrison, Ocean Vuong, and Alison Bechdel.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-242 American Woman Writers

Intermittent: 9 units
In 1855, Nathaniel Hawthorne lamented to his publisher that "America is now wholly given to a damned mob of scribbling women and I should have no chance of success while the public taste is occupied with their trash." Even today, The New York Times Book Review and other gatekeepers rarely give women writers the coverage that male writers receive. In this course we will trace the multiple traditions of 20th century American women's writing and examine how women writers question, resist, subvert, and revise traditional gender roles. Our readings will address: the social construction of gender; the relationship between gender and genre; the cultural positions of women as writers and readers; women's rights and suffrage; women and work; female sexuality and sexual freedom; constructions of motherhood; intersections of gender with race, class, and ethnicity. Readings include: The House of Mirth, Pale Horse Pale Rider, Their Eyes Were Watching God, Raisin in the Sun, To be Young, Gifted and Black, Woman Warrior, Fun Home, and The Namesake. Every other week (or so) we will be reading excerpts from Feminist Literary Theory and Criticism.

76-244 Immigrant Fictions

Intermittent: 9 units
Contemporary writers offer vibrant portrayals of questions around identity and belonging that accompany migration and immigration to the United States. Their works show how displaced people and their children reinvent themselves, even as they look back to other homelands. This contemporary literature course combines fiction, poetry, drama and scholarly non-fiction readings to examine the experiences of the transnational movement of people to the United States, including international students, refugees, and documented and undocumented migrants and their families. We will consider not only the experience of personal migration, but also the global social, economic and political processes that structure that movement. Possible fiction readings draws from Asian American studies, Latinx studies, and African American studies, and might include Jhumpa Lahiri, Valerie Luiselli, Chimamanda Adichie, Christina Garcia, Juno D and #237;az, Lisa Ko, Cathy Park Hong, and Edwidge Danticat.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-245 Shakespeare: Tragedies & Histories

Spring: 9 units
For F24 only: In the closing decades of the sixteenth century, enterprising cultural producers in early modern London began to develop a new commercial venture called 'playing': a business that offered ordinary people a few hours of dramatic entertainment for the price of one penny. In addition to watching the professional players onstage, spectators also participated in a form of play themselves (in a sense) because theatrical experience provided a unique opportunity to engage imaginatively with otherwise inaccessible people, worlds, and ideas. More than four hundred years later, the drama of the period now ranks among the most esteemed texts in all English literature, and the name 'Shakespeare' has become a byword for literary genius. This course will offer an overview of Shakespeare's tragedies and histories. As we read through a selection of key works, we will endeavor to understand what, and how, they meant in their original context, thereby developing a historically informed perspective on their influence over our own cultural landscape. The course counts toward the GenEd requirement, and is also part of the CMU Prison Education Project. Classes will take place at Somerset State Correctional Institution. CMU students will study alongside incarcerated students. A bus will provide transport for the students from CMU. Students will have to fill out a brief questionnaire before enrolling.

Course Website: https://www.cmu.edu/dietrich/students/undergraduate/programs/pep/index.html (https://www.cmu.edu/dietrich/students/undergraduate/programs/pep/)

76-247 Shakespeare: Comedies and Romances

Fall: 9 units
Sometime around the late sixteenth century, enterprising cultural producers in early modern London began to develop a new commercial venture called 'playing': a business that offered ordinary people a few hours of dramatic entertainment for the price of one penny. In addition to watching the professional players onstage, spectators also participated in a form of play themselves, in a sense, because theatrical experience provided a unique opportunity to engage imaginatively with otherwise inaccessible people, worlds, and ideas. More than four hundred years later, the drama of the period now ranks among the most esteemed texts in all English literature, and the name 'Shakespeare' has become a byword for literary genius. This course will offer a selection of Shakespeare's delightfuland sometimes surprisingly edgycomedies and late romances. As we read through these works, we will endeavor to understand what, and how, they meant in their original context, thereby developing a historically informed perspective on their influence over our own cultural landscape.

76-253 Information Graphics

Intermittent: 3 units
This micro-course introduces the basics of designing information graphics to students in all disciplines who are interested in learning to communicate complex information clearly and ethically using information graphics. Information graphics are ubiquitous. They are used by both practitioners and academics across many disciplines to communicate complex ideas, processes, and systems. While millions of decisions are made based on information graphics daily, creating an effective graphic is not simple. Designing information graphics requires careful consideration from multiple perspectives, including visual perception, social psychology, semiotics, and design ethics. What makes information graphics effective? What is required to optimize the design of an information graphic? How should information graphics be evaluated? Can information graphics be neutral, without bias? In this introductory course, we will address these and other questions through a hands-on project and discussions on various threads of studies around the analysis of information graphics. Assigned readings will complement the projects allowing students to examine information graphics from the perspectives of relevant theories and research findings. Class discussions and critiques are an essential part of this course.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-259 Film History

Fall: 9 units
This introductory course will focus on the history of the American film industry, 1930-1980. On most weeks, we will screen two films that reflect the most important genres and most enduring achievements of the era. We will be concerned with understanding how the studio system produced and marketed these works, and how that system changed significantly from the 1950s-1970s. By focusing on individual studios (for example, MGM and Warner Bros.) as "test cases," the class will also examine how particular companies produced films of a certain type in terms of such parameters as genre, theme, player, class address, and/or style. Readings will deal with the history of Hollywood, the various films, stars and/or filmmakers considered, as well theoretical/critical issues such as authorship, reception, and high vs. low culture. Students will learn important skills for film history, including reception study, archival research, and contextual analysis. Grades will be based on three papers that require different kinds of historical research, a midterm, and a final.
Prerequisite: 76-239

76-260 Introduction to Writing Fiction

Fall and Spring: 9 units
This is an introduction to the reading and writing of short fiction. Character development and the creation of scenes will be the principal goals in the writing of short stories during the course of the semester. Revisions of the stories will constitute a major part of the final grade. Reading assignments will illustrate the different elements of fiction reviewed and practiced, and students will analyze and discuss stories from a writer's point of view.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

76-261 Intro to Writing Creative Nonfiction

Intermittent: 9 units
This course will expose you to several contemporary Creative Non Fiction writers, while helping you connect with your own life stories so that they can be shaped into narratives. You'll be reading and analyzing both short and long form non fiction, so as to learn the elements of the art and craft of this genre. A high priority will be given to creating a community spirit in our class, so as to inspire you and your writing through connections not just to professional writers, but to the writers who will be your classmates.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-265 Introduction to Writing Poetry

Fall and Spring: 9 units
This course is meant to serve as an introduction to the craft of poetry. We'll look closely at traditional forms in an effort to understand the effects of more formal choices on the page, and we'll examine the craft choices of modern and contemporary poets to expand our understanding of poetic approaches. Our analysis of poetry will begin at the level of the syllable and progress to words, lines, stanzas, series, and collections. You will be required to read both published work and the work of your classmates with a critical eye, to write your own poems, both formal and not, to write several short analysis essays, to write a longer critical essay, and to demonstrate your knowledge on one in-class exam. The most important take-away from this class is the ability to talk knowledgeably and critically about poetry. What you learn here will pave the way for your future as both a writer and a reader.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-269 Introduction to Screenwriting

Fall and Spring: 9 units
This is a course in screenplay narrative. The screenplay has a certain format observed by every screenwriter. It is not so difficult to learn the format. The difficulty is in developing a screen story populated by believable characters, creating an expressive and logical relationship between the scenes by manipulating screen space and screen time (knowing what to omit from the story and what to emphasize), and finally writing dialogue that sounds real, but that does not simply copy everyday speech. The class will be structured into weekly writing exercises, discussion of the narratives under consideration, presentation and discussion of student work, and a final writing project.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-270 Writing for the Professions

All Semesters: 9 units
Writing in the Professions is a writing and communication design course for mainly sophomores and juniors (although it can be relevant for some freshmen and seniors) in all majors other than English. The course is appropriate for upper-level students in all CMU colleges and assumes that they may not have had much college-level writing instruction beyond the first year. The basic idea of the course is to give experience in developing the design skills for writing and communicating as students transition from student to professional. The course will cover some foundational principles of designing multimodal writing and communication within a variety of tasks including resume and cover letter writing, proposal writing and writing instructions. Students will discern the difference between writing for general and specific audiences, and analysis of visual aids in various texts. The course requires that students work both independently and in groups. All sections of 76-270 align with particular core objectives. However, some sections of 76-270 are discipline-focused and reserved for students from specific programs or colleges. Students should review the section title before attempting to register to discern which section is most appropriate for them. Dietrich College students can count any 76-270 section toward their GenEd requirement: Disciplinary Perspectives-Design.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

Course Website: https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/index.html (https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/)

76-271 Introduction to Professional and Technical Writing

Spring: 9 units
Professional and technical communicators use words and images to connect people with information. With a strong foundation in rhetoric, this course will sharpen your abilities to communicate information clearly, effectively, and responsibly to real readers, stakeholders, and decision makers. Our assignments and conversations will include a wide range of genres and rhetorical situations you can expect to encounter as a professional and technical communicator, including job application genres, narrative genres like feature articles that blend subject matter interviews with keen observation, research genres like proposals, and team writing genres like technical documentation. A high level goal for the course is to combine theory, methods, and best practices for putting real readers and users of information at the center of our communication strategies. By the end of the course, you will have a portfolio of polished work that you can use to narrate your professional strengths and interests. This course is designed for undergraduates pursuing majors and minors in a writing and communication field, and who want to explore professional and technical communication as a discipline and career area.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-275 Introduction to Critical Writing

Fall: 9 units
(This course was formerly titled Critical Writing Workshop.) The goal of this course is to sharpen your ability to read and write about literary and other imaginative works. Critical reading and writing mean gathering and evaluating language and images to form an interpretation of a print, visual, or other media text. To that end, you will learn analytical keywords and terms from literary and cultural theory and how to apply them to texts and other objects. The focus will be on theories of race, gender and empire and how they inform literary texts and our reading of them. Our course's method for critical writing instruction will be to workshop drafts of your essays. To that end, you will write four short interpretive papers in the course. You will also gain practice at oral presentation, peer-review and critique. Since this is a writing workshop and our time for reading will be somewhat limited, we will read a several shorter literary texts in a range of genres (fiction, drama, poetry) while we consider questions of form. The communication and analytic skills you acquire in this class will transfer to your work in a wide range of academic disciplines and professional contexts.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-278 Japanese Film and Literature: The Art of Storytelling

Intermittent: 9 units
This course explores how the art of storytelling is in tandem with the vicissitudes of the human condition as illustrated in Japan's variety of fictions, non-fictions, and films in the twentieth and twenty-first centuries. Analyses of each storytelling not only reveal the cultural dynamics behind Japanese modernity, but also invite students to find new insights into Japanese culture and their ways of perceiving our globalized world. What kind of cultural exchanges took place between modern Japan and the West? How are Japan's traditional values transformed in the face of modern technicalization and industrialization, compared to the modernization of other countries? And, in turn, what kind of impact has modern Japanese culture had on today's world? Tackling these questions among others, the course also extends to such issues as the legacy of traditional Japanese culture, the modern Emperor system, World War II experiences, emerging voices of minorities, and popular culture (e.g., anime and subculture).

76-282 Disability in Pop Culture

All Semesters: 9 units
In 2016, ABC debuted the show Speechless, which follows the life of JJ, a high school teenager with cerebral palsy. In 2015, Deaf West Theatre premiered a revival production of Spring Awakening on Broadway, debuting a cast of both deaf and hearing actors who performed the show using American Sign Language and English simultaneously. In 2013, Allie Brosh released a book version of her blog titled Hyperbole and a Half: Unfortunate Situations, Flawed Coping Mechanisms, Mayhem, and Other Things That Happeneda combination of web comics and stories that included discussions of depression. These examples are a mere few of more recent representations of disability in pop culture. In this course, we will investigate how representations of disability tell stories about difference. Using the tools of rhetorical analysis, we will ask the following questions: How do memoirs, films, comics, health initiatives, advertisements, blogs, laws, and poetry use language and images to influence or construct our understanding of disability? How do these representations engage differences of gender, race, class, and sexuality? And finally, how does this work expand broader cultural, aesthetic, and political views of embodiment, disability, and difference? This course has two major parts: 1) We will examine various models of disability in order to theorize concepts such as normal, the gaze, passing, and access. In the process, we will consider how these concepts intersect with gender, race, class, and sexuality. 2) We will engage these theories through close reading of actual representations of disability that circulate in our worlds around us and shape our understandings of disability. We will pay particular attention to the rhetorical elements central to these representations such as purpose, genre, audience, context, form, and style.

76-286 Oral Communication

Intermittent: 6 units
Oral presentations are essential to professional success. Yet many people find themselves growing weak in the knees at the thought of presenting in front of a group. They read off of notes, speak too fast, or pepper their speech with nervous filler words such as "um" or "you know." 76-286 Oral Presentations is a mini intended for students who want to boost their confidence in presenting in front of others. You will learn strategies for structuring the content of a presentation, designing effective presentation slides, and controlling your voice and body language to produce a smooth, confident-sounding oral delivery. We will begin with giving short informal presentations and gradually increase the stakes as your confidence improves. You will have weekly opportunities to practice and improve your skills. We will also find opportunities to practice in a variety of physical settings so you can envision yourself as a calm, confident speaker no matter your surroundings. Grades in the course will be based on improvement and effort to encourage students to focus on their development rather than on final outcomes.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-108 and 76-106)

76-287 Sex & Texts

Intermittent: 9 units
Please see *Content Warning* Below In this course, we will consider how writing and communication serve as means to create, define, and bound our worlds, shaping our ideas about "sex" and "sexuality" at their intersections with gender, disability, race, geographic location, religion, age, and so on. Using a rhetorical perspective, we will interrogate how everyday experiences with and performances of sex and sexuality are tied to legal, medical, corporate, cultural, and historical practices and ideologies. Readings will consist of public, scholarly, and creative genres such as Roxane Gay's Unruly Bodies, Judith Butler's Gender Trouble, Cardi B's "WAP" (feat. Megan Thee Stallion), and the Hulu series Shrill and will address topics including but not limited to bathroom bills, rape culture, the beauty industry, intellectual property, citizenship, and marriage equality. Students in this course will 1) develop a vocabulary for talking about sex and sexuality; 2) examine how sex and sexuality are shaped by public, historical, and cultural norms; and 3) practice analyzing rhetorical elements such as purpose, genre, audience, context, form, and style. Student projects will include weekly discussion posts, two shorter papers, and one creative project. This course meets the Dietrich College Communicating Gen Ed requirement. *Content Warning* Because this course takes up questions of sex and sexuality, we will discuss the body/embodiment and issues related to violence (sexual, racial, intellectual, domestic, linguistic, etc.). While projects will ask students to examine questions of sex and sexuality, students will not be required to write about issues related to violence.

76-289 Billingual & Bicultural Experiences in the US

Intermittent: 9 units
What does it mean to be bilingual in the USA, when approximately 80% of Americans are monolingual English-speakers? In this course, we will learn about the nature and experience of bilingualism and biculturalism (past and present) and how it shapes different perspectives and worldviews and #8212;within an individual, between individuals, and on a larger (societal, cultural) level. The course highlights the experiences of groups such as immigrants, racial/ethnic minorities, indigenous communities, and users of signed languages to foreground experiences that may be similar to or different from those of the students. We use a variety of resources (e.g., social media, film and documentaries, historical documents, literature, music, art) to accomplish this, and students are encouraged to be creative in the ways they design their own hands-on projects. This discussion-based course is taught in English and is open to all students, whether they identify as bilingual/bicultural, or are simply interested in the course topic.

76-290 Literature & Culture in the 20th Century

Intermittent: 9 units
Topics vary by semester and instructor. For example: Spring 2020: Black Fiction This course will take a transatlantic approach to what constitutes black literature and artistic expression from the nineteenth until the early twenty-first century. We will investigate how black authors use literature and other mediums of expression for social, political and self-presentation. Our primary focus will be on fiction with some memoir, poetry and non-fiction essays thrown into the mix. We will cover canonical black writers of the diaspora as well as key literary periods and movements. Along with these more conventional ways of accounting for literary history we will look at the way gender, sexuality, (trans) national belonging, ideology and political economy shape the reception, aesthetics and context of black writing. Authors covered in this course include: Fredrick Douglass, Nella Larson, Audre Lorde, Ralph Ellison, Melvin Tolson, Percival Everett, Merle Collins, Claudia Rankine and Tayari Jones to name a few.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-108) or (76-106 and 76-107) or (76-108 and 76-107)

76-291 Getting Heard/Making a Difference

Intermittent: 9 units
How can a college student get people to pay attention to a problem, whether it is a personal, social, environmental, ethical, or public issue? In particular, how do people who don't already have what is called "standing"such as the authority or credentials to speakget their community to listen? In this course you will learn how to create real dialogue and carry out effective (not simply adversarial) engagement within a university and later in your professional lives. It introduces you to the rhetorical art of savvy, issue-centered social engagement. Drawing on research, theory, and our own campus investigation, we will try out methods for collecting competing perspectives, for framing a shared actionable problem, and for creating well-supported, persuasive and motivating accounts in proposals, reports, editorials, stories, or media. The theory and strategies we study are designed to create what is called a rhetorical presence for your ideas, to put them into circulation, and help create a more engaged local public. This course meets the Dietrich College Communicating Gen Ed requirement.

76-292 Introduction to Film Production

Fall: 9 units
This course is an introduction to the process of filmmaking. Students will develop a personal cinematic language and create a short final film from the ideation, to the synopsis and shot list, the set then to the editing room. The course will introduce technical tools to create audio and visual forms that serve the content developed in a film treatment through filming assignments, planning and producing a short film, peer review and group work. The focus will be on understanding shots and coverage of a scene, the various aspects of the cinematic language, with an emphasis on the basic visual components such as space, movement, and rhythm - and how they are used to tell the story visually. Audio layering to create a meaningful soundscape and the art of Editing will be discussed extensively.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-293 Writing about Research in Your Discipline

Intermittent: 9 units
This course introduces the characteristics and types of writing required of students at advanced undergraduate and beginning graduate levels while building sentence-level editing skills. Topics addressed include the role of writing in the academy, the writing process including editing and revision strategies, expectations for content associated with different genres, bibliographic styles and reference management software, and an introduction to the reporting of empirical research. Students will work through modules on sentence structures associated with academic language as well as workshop their own writing projects. This course is appropriate for students considering writing a senior thesis and/or applying to graduate school.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

Course Website: https://www.cmu.edu/dietrich/english/courses/fall-2020-course-descriptions.pdf

76-295 Russian Cinema: From the Bolshevik Revolution to Putin's Russia

Fall: 9 units
"Last night I was in the kingdom of shadows," said the writer Maxim Gorky in 1896 after seeing a film for the first time. "How terrifying to be there!" Early film inspired fear and fascination in its Russian audiences, and before long became a medium of bold aesthetic and philosophical experimentation. This seminar-style course surveys the development of Russian and Soviet film, paying equal attention to the formal evolution of the medium and the circumstanceshistorical, cultural, institutionalthat shaped it. We will examine Sergei Eisenstein's and Dziga Vertov's experiments with montage in light of the events of the Bolshevik Revolution and the directors' engagement with Marxism; Georgi Alexandrov's and the Vasiliev brothers' Socialist Realist production against the backdrop of Stalinist censorship; Andrei Tarkovsky's and Kira Muratova's Thaw-era films within the broader context of New Wave Cinema; and the works of contemporary directors, including Aleksei Balabanov, Alexander Sokurov, and Andrey Zvyagintsev, in connection with the shifting social and political landscape of post-Soviet Russia. Besides introducing students to the Russian and Soviet cinematic tradition, this course will hone their skills in close visual analysis. No prior knowledge of Russian language or culture is required. The course is conducted in English, but students will have the option to do work in Russian for three extra course units.

76-296 20th Century Russian Masterpieces

Intermittent: 9 units
At the beginning of the 20th century, the Russian Empire underwent a series of dramatic changes in quick succession: industrial modernization, the unsuccessful 1905 rebellion, terrible losses in the First World War, finally culminating in the 1917 October Revolution. The literature and culture of the era were deeply impacted by these upheavals as artists and writers of the era attempted to capture and convey the world rapidly shifting around them. This course will acquaint students with canonical texts from 20th-century Russian literature and will also examine the highly specific context in which they were produced. From the fin-de-si and #232;cle aesthetics of a crumbling Russian Empire to the avant-garde experimentalism of the Russian Revolution and Civil War era, to the establishment of Socialist Realism and the implementation of a Totalitarian regime under Stalin, the course invites students to think about both the realities of life and artistic production in a rapidly transforming country as well as the ways in which these works bring contemporary readers to the inner lives of Soviet citizens.

76-300 Professional Seminar

Fall: 3 units
This weekly, 3-unit seminar is designed to give professional and technical writing majors an overview of possible career and internship options and ways to pursue their professional interests. Each session will feature guest presenters who are professionals working in diverse communications-related fields such as web design, journalism, public relations, corporate and media relations, technical writing, medical communications, and working for non-profits. The visiting professionals talk about their own and related careers, show samples of their work, and answer student questions. The course is required for first-year MAPW students and is open to all English undergraduates, who are urged to participate in their sophomore or junior years to explore options for internships and careers.

76-301 Internship

All Semesters
This course is designed to help you explore possible writing-related careers as you gain workplace experience and earn academic credit. You'll work on- or off-campus as an entry-level professional writer for 8-10 hours per week in a field of interest to you (public relations, journalism, advertising, magazine writing, non-profit, healthcare, etc.). You are responsible for finding an internship. Most of your class time for the course will be completed at your internship site - a minimum of 120 hours (8-10 per week) over the semester for 9 units of credit. As the academic component of the course, you'll keep a reflective journal and meet periodically with the internship coordinator to discuss your internship and related professional issues. You must register for the course before the add/drop deadline of the semester in which you want to do your internship. Before you can register, you must contact the internship instructor listed above to express your interest in the course and to be cleared for registration. Credit for the internship course cannot be retroactively awarded for past internships.

76-302 Communication Support Tutoring Practicum

Fall
The Communication Support Practicum is designed to introduce students to communication scholarship and pedagogy as well as the methods and theories that inform them for the purpose of communication support and tutoring in CMU's Student Academic Success Center. Students will explore communication (written, oral, and visual) in multiple disciplines and genres with a focus on gaining knowledge and skills to respond to communicators and their texts. Lectures, discussion, and assignments will offer a chance to think critically about tutoring practices and the ideologies and values on which they are based as well as ways to challenge the bias inherent in them. There will be many occasions to reflect on and evaluate tutoring skills, observe others in tutoring situations, and practice a variety of methods that consider the different needs of communicators. Students will gain awareness of how various spaces, identities, technologies, and abilities inform textual production as well as how to create a meaningful response to meet the diverse needs.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

Course Website: https://www.cmu.edu/gcc/faqs/index.html (https://www.cmu.edu/gcc/faqs/)

76-303 Independent Study in Creative Writing

All Semesters
An Independent Study course is a course taken with faculty supervision that goes beyond the courses offered in a particular area of interest. It should not duplicate a course offered in the regular schedule of classes. A student wishing to take an independent study needs to locate a faculty member whose research interests are close to the area of proposed study and meet with the faculty member to discuss whether it is something the faculty member is interested in doing. The department requires that the student and instructor submit a written contract (available in the English Department) detailing the expectations (description of course of study, readings, how often the student/faculty member will meet) and requirements for the completed independent study project (number and amp; length of papers) and a time-line for completion of the work. You should think of this as developing the equivalent of a detailed course syllabus/schedule, and typically involves development of a bibliography of readings.

76-306 Editing and Publishing

Fall and Spring
Note: Registration in this course is by permission only. In this course students will work closely with the editors of Carnegie Mellon University Press to learn many of the facets of producing books. These range from business management and marketing to the elements of editing, book design, and production.

76-307 Advanced Editing and Publishing

Fall and Spring
Note: Registration in this course is by permission only. In this course students will work closely with the editors of Carnegie Mellon University Press to learn many of the facets of producing books. These range from business management and marketing to the elements of editing, book design, and production.
Prerequisite: 76-306

76-308 Literary Journal Publishing

Intermittent
In this course, students will learn about the landscape of and publication process for literary journals in the United States. We will read a variety of literary journals in print and online, will host guest speakers, and will do a variety of hands-on activities related to editing and publishing. Students will gain experience by working on The Oakland Review, an international literary journal run out of CMU, in capacities as varied as editorial, design and production, or promotion. If you are interested in registering for this course, please go to the Course URL and fill out the questionnaire. Thank you.
Prerequisites: 76-265 or 76-260

Course Website: https://form.jotform.com/CMUEnglish/literary-journal-publishing-course (https://form.jotform.com/CMUEnglish/literary-journal-publishing-course/)

76-310 Advanced Studies in Film and Media

Spring: 9 units
This course will focus on several key technical components of filmmaking and the ways they function within the film text, as well as the ways they can be read as an indication of the underlying ideology of a work. Individual units of the course will concentrate on performance, production design, photography, editing and music. Films will be drawn from a variety of national cinemas from around the world. A primary goal of the course will be the development of skills useful for filmmaking, film analysis and scholarship. Students will engage in focused projects designed to facilitate the pedagogical goals of each unit.
Prerequisite: 76-239

76-311 Independent Study in Humanities Analytics

Intermittent
An Independent Study course is a course taken with faculty supervision that goes beyond the courses offered in a particular area of interest. It should not duplicate a course offered in the regular schedule of classes. A student wishing to take an independent study needs to locate a faculty member whose research interests are close to the area of proposed study and meet with the faculty member to discuss whether it is something the faculty member is interested in doing. The department requires that the student and instructor submit a written contract (available in the English Department) detailing the expectations (description of course of study, readings, how often the student/faculty member will meet) and requirements for the completed independent study project (number and amp; length of papers) and a time-line for completion of the work. You should think of this as developing the equivalent of a detailed course syllabus/schedule, and typically involves development of a bibliography of readings.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-312 Crime and Justice in American Film

Intermittent: 9 units
Films dealing with criminal activities and criminal justice have always been popular at the box office. From the gangsters of the Thirties and the film noir of the Fifties to the more recent vigilante avenger films of Liam Neeson, the film industry has profited from films about crime and its consequences. How those subjects are portrayed, however, tells us a great deal about larger trends in American history and society. Every imaginable type of criminal activity has been depicted on screen, as have the legal ramifications of those acts. But these films raise profound questions. What is the nature of crime? What makes a criminal? Are there circumstances in which crime is justified? How do socioeconomic conditions affect the consequences? How fair and impartial is our justice system? Perhaps most importantly, how do depictions of crime and justice in popular media influence our answers to these questions? This class will utilize a variety of films to discuss the ways in which popular media portrays the sources of crime, the nature of criminals, the court and prison systems, and particular kinds of criminal acts. Films to be screened may include such titles as The Ox-Bow Incident, Out of the Past, 12 Angry Men, Young Mr. Lincoln, Brute Force, The Equalizer, Jack Reacher and Minority Report. By thoroughly discussing these films and related readings we will be able to trace the various changes in attitude towards crime and justice in America over the last century.

76-313 Creative Visual Storytelling in Film Production

Intermittent: 9 units
Visual storytelling cuts to the heart of the filmmaking process, combining all elements of the craft to engage the viewer. Every picture is comprised of a story, visuals, and, sometimes, sounds. This class is about learning how to understand and control time-based images to better tell your story. We will learn essential skills for becoming a creative technological storyteller - how to think visually and aurally. Fundamental focus will be on understanding the basic visual components -using space, tone, line, shape, color, movement and rhythm- and how they are used to visually tell a story, define characters, communicate moods, emotions, thoughts and ideas. We often are not consciously aware of them within a film but are critical in establishing the relationship between story structure and visual structure. Through readings, film analysis, creative brainstorming, assignments and individual critiques this class will guide each student into translating their creative vision into a short final film.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-314 Data Stories

Fall: 9 units
Every dataset has a story. In the age of big data, it is vital to understand the unlikely casts of algorithms, data miners, researchers, data janitors, pirates, data brokers, financiers, etc. whose activities shape culture. This course will feature a range of "farm to table" data stories, some going back hundreds of years, and introduce students to resources and strategies for contextual research. It will explore cases such as the London cholera epidemic, Google Books, Netflix, the Oxford English Dictionary, the Strava map, and the Queen Nefertiti scan alongside several pieces of art and fiction that capture aspects of data stories typically obscured elsewhere. Research methods introduced will include book history, media archeology, history of information, infrastructure studies, ethnography, narratology, and digital forensics. Students will read scholarly articles, novels, journalism, and popular non-fiction; they will test algorithms; and they will develop individualized long-form research and writing projects informed by computational methods in data studies, journalism, and art.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-315 19th Century American Literature

Intermittent: 9 units
These days, it's pretty easy to get to Walden Pond. It's right off route 126 South (not too far from Concord) and there is a nice little farm stand there called the Farm at Walden Woods, where you can get corn and raspberries and freshly baked bread. In this class we'll go back in time to the Walden Pond of Thoreau's time, with a focus on the Green Nineteen and #8212;-writers and thinkers who considered the relationship between human civilization and the American wilderness (Thoreau, Emerson and Hawthorne). We will think about the interrelationship between the environment and nascent capitalist industries by reading the poetry and prose by young women who worked in the Lowell Mill (The Lowell Mill Offerings). We will also think about the environment in relation to two slave narratives (Douglass, The Slave Narrative of Frederick Douglass and Harriet A. Jacobs, Incidents in the Life of a Slave Girl. Finally we will consider the environmental consciousness of the two most important poets of the 19th century, Walt Whitman and Emily Dickinson. As for coursework, we will use the class to practice meditation, natures walks, and one group project in which you will design your own environmentally conscious Utopian community.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-316 Topics in Literature: Watching HBO's The Watchmen

Intermittent: 9 units
This course is centered on the graphic, social and political universe created by HBO's The Watchmen series. Course viewings/readings will include: the 9-episode HBO series from 2019, the original The Watchmen comic series from the 1980s, and various cultural influences on the HBO series, including the musical Oklahoma, and the 1930s era singing group the Ink Spots, whose hit, "I Don't Want to Set the World on Fire," is featured in the series. The course will include the intro to film studies text, Writing about Movies, and one of the goals of the course will be for students to write original, accessible, and interesting 1000 word essays about the series to be published on a public website.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-317 Contemporary American Fiction

Intermittent: 9 units
No one seems to know quite how to define contemporary American fiction. It's clear that fiction has changed since the 1960s and 70s, the heyday of postmodernism, but it's hard to pin down what characterizes the work that has come since. In this course, we will read a selection of American fiction from the 1980s to the present and try to get a sense of its main lines. In particular we'll look at the turn to "genre," the expansion to multicultural authors, and the return to realism. Also, we will consider how it relates to American society. Authors will include authors like Chimamanda Ngozi Adichie, Alison Bechdel, Jennifer Egan, Emily St. John Mandel, Weike Wang, and Colson Whitehead.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-318 Communicating in the Global Marketplace

Intermittent: 9 units
Effective intercultural and global communication has become increasingly salient in today's hyper-connected world, simultaneously presenting us with challenges and rewards. A vivid thread that unspools once one begins to unravel the embroidery of intercultural and global communication in contemporaneous times is computer-mediated communication (CMC) and social media. With more than half of the world's population connected to the Internet, we are more connected than ever. But, despite how seamless the Internet may have made communication, the fact that language is rooted in culture complicates CMC, even if the language is English. The omnipresence of English leads people to assume that a common language implies a shared understanding of a given topic. But, speaking the same language does not mean we share the same cultural values, or that we even understand or are aware of other cultural values and beliefs. English may be the lingua franca in many organizations and professional settings, but the commingling of globalization and CMC raises some questions including "How can professional communicators contribute to shaping a workplace discourse that transcends national or regional borders to reach a global audience"? This course will address these questions by explaining the specific ways in which our backgrounds (from personal to social and even national) influence professional and technical communication; the impact of globalization on the workplace, especially in times of crisis; and the ways in which we can rely on general concepts and principles in order to communicate effectively in specific international settings and situations.
Prerequisites: 76-270 or 76-271 or 76-272

76-319 Environmental Rhetoric

Fall: 9 units
Should you take a hike or seize the mic? Environmental rhetoric combines commitment with contention We start by exploring its multiple discourses, from Muir's vision of conservation, to Leopold's introduction of ecology, to Carson's call for public action, to contemporary scientific research and competing public discussions. To uncover their hidden logic, we study rhetorical strategies first, for analyzing arguments (over issues such as wolves, clean water, or sustainable design), and then for communicating risk (in the face of climate change, fracking, as well as wind power). In response, this course will prepare you to act as a research-based rhetorical consultant for a group of your choice, analyzing the issues and arguments it faces, in order to propose a rhetorically effective response, supported by your own imaginative prototype of a brochure, web page, press release.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-323 Text to Screen

Intermittent: 9 units
This course is an introduction to the fundamentals of narrative filmmaking and the attendant creative processes. Students will explore the symbiosis between film literature, visual storytelling, team building and the practical planning essentials universal to making film.
Prerequisite: 76-269

76-324 Topics in Rhetoric: Language and Place

Intermittent: 9 units
TBD
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-108 and 76-106)

Course Website: http://www.cmu.edu/dietrich/english/index.html (http://www.cmu.edu/dietrich/english/)

76-325 Intertextuality

Spring: 9 units
What do we mean when we say that someone has "twisted" our words, or that our words have been "taken out of context"? Why is Martin Luther King Jr. best remembered for saying, "I have a dream," and not for saying, "War is the greatest plague that can affect humanity"? What are political "talking points" and how are they perpetuated? How does a claim (unfounded or not) become a fact? How does a fact become a myth? These are just some of the questions that we will consider. More specifically, this is a course in how meaning changes as texts created in one context and for specific purposes are repeated, cited, and used in other contexts and for other purposes, sometimes related and relevant, sometimes not. More technically, we'll be focusing on the rhetorical nature of intertextual discourse. Our goal will be to examine the ways that people of all kindsincluding politicians, journalists, and scientistsstrategically draw upon and transform the statements, arguments, and evidence of other people to promote their own viewpoints or purposes. We will begin by investigating scholarship that views language as an extended conversation in which people struggle to have their own voices heard, and other voices countered or even suppressed. Later, we will survey a number of studies that suggest how individuals and organizations recontextualize and reinterpret prior discourse for persuasive ends. More specifically, we will analyze how the micro-features of the language (for example, qualifications, evaluations, and attributions) are used to persuade audiences that certain assertions are (not) factual, that certain speakers are (not) authoritative, and that certain proposed actions are (un)desirable. Ultimately, you can conduct your own research on intertextual rhetoric on a topic of specific interest to your academic or professional goals.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-326 Contemporary Global Literature

Intermittent: 9 units
In this course, students will read, interpret, discuss and write about novels and short stories written in English in the past ten years by writers originally from Africa, South Asia, East Asia and the Caribbean. While these works represent the "large stories" of economic globalization, refugee migration, and ecological catastrophe, they are crafted around the "small stories" of love, longing, friendship and family.We will talk about both kinds of narratives, tracing the entanglements of one in the other.Students will reflect on the relationship between history, society and culture in a global context, situating the contemporary within the longer trajectories that mark the legacies of colonialism and imperialism. This course is virtual and almost entirely synchronous; barring unexpected situations, attendance is expected for what should be a lively class discussion.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-327 Equity & Communication: Strategies for Institutional Change

Intermittent: 9 units
Communication is always embedded in power relationships with unstated social rules that govern who is able to say what when. But communication also offers us a tool for rewriting oppressive social scripts. In this class, we will look both at inequities built into our communication and strategies for overturning these inequities. The focus will be on practical actions that you can take to improve your school, workplace, or extracurricular groups. Our readings will come from diverse sources and fields, including sociolinguistics, psychology, education, organizational communication, and writing studies. While our readings might occasionally depress (or enrage) you, the overall focus of the course will be optimistic, challenging you to imagine solutions to the problems we discuss.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-328 Introduction to Corpus Linguistics

Intermittent: 9 units
This is a hands-on, project-based class that will help students build a methodological toolkit for computer-based textual analysis. That toolkit will include methods for the collection of data, its processing via off-the-shelf software and some simple code, as well as its analysis using a variety of statistical techniques. In doing so, the class offers students the opportunity to engage in scientifically oriented inquiry, giving priority to the use of corpus evidence to answer research questions. The first part of the term will be devoted to introducing fundamental concepts and taking a bird's eye view of the potential application of corpus methods in domains like academic writing, technical communication, and social media. From there, students will initiate projects of their own choosing and develop them over the course of the semester. The goal is to acquaint students with the strengths and limitations of computer- based textual analysis and to provide them with the necessary foundational skills to design projects, to apply appropriate quantitative methods, and to report their results clearly and ethically to a variety of audiences. This class requires neither an advanced knowledge of statistics nor any previous coding experience, just a curiosity about language and the ways in which identifying patterns in language can help us solve problems and understand our world.

76-329 Performing Race in Early Modernity

Intermittent: 9 units
The earliest known use of the term "white" in reference to Europeans occurs in The Triumphs of Truth, a 1613 play by Shakespeare's contemporary, Thomas Middleton. In addition to suggesting an important connection between race and drama in 17th-century England, this simple historical note raises a range of questions that have a direct bearing on some of the most pressing issues of the 21st century: Where do ideas about race come from? By what processes do the distinctions of racial concepts emerge, evolve, calcify, and mutate? How does the conceptualization of race relate to media? How do racial representations bolster and conduct political power? In this course, we will broach these questions by taking a close look at the race-making function of drama in early modernity, a period when race was an inchoate, incipient concept, caught up with the emergence of colonialism, capitalism, and increasing interconnection between peoples, cultures, and worlds. As we think, read, and converse together, we will endeavor to come to terms with the problems and paradoxes of racial representation in the early modern theater, a forum that offered access to innovative, daring thinking about human equality and ethical responsibility, but was also a site for the perpetuation of hateful stereotypes and exploitative theories of white supremacy. In a wide-ranging survey of drama, historical documents, and contemporary criticism, we will work toward an understanding of how race-based concepts operated in the theater, and how the drama early of modernity continues to influence thinking about race in our own time. This course meets the Dietrich College Reflecting Gen Ed requirement.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-332 Writing about Research in Your Discipline

Intermittent: 9 units
This course introduces the characteristics and types of writing required of students at advanced undergraduate and beginning graduate levels while building sentence-level editing skills. Topics addressed include the role of writing in the academy, the writing process including editing and revision strategies, expectations for content associated with different genres, bibliographic styles and reference management software, and an introduction to the reporting of empirical research. Students will work through modules on sentence structures associated with academic language as well as workshop their own writing projects. This course is appropriate for students considering writing a senior thesis and/or applying to graduate school.
Prerequisite: 76-101

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-335 20th and 21st Century American Fiction

Intermittent: 9 units
This course will examine American fiction from 1900 to the present. It will cover the movement from modernism, through midcentury realism and postmodernism, to the contemporary. We will look at scholarly definitions of those modes, as well as some of the cultural context that has informed American literature. Some of the authors will include modernists like Stein and Faulkner; midcentury writers and postmodernists like Ellison, McCarthy, and Pynchon; and contemporary writers like Diaz, Lahiri, and Franzen.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-108 and 76-106)

76-337 Intersectional Feminism

Intermittent: 9 units
The concept of intersectionality first appeared in African-American feminist legal theory, but it rapidly spoke to other ideas and movements authored by other women positioned on the margins in the United States and beyond. Now widely disseminated as a feminist practice embraced by many identities, intersectional feminism acknowledges how interlocking power structures produce systematic oppression and discrimination to create distinctive gender identities in terms of such aspects as sexuality, race, ethnicity, class, religion, language (and accent), and neuro- and physical diversity. In this class, we will consider a wide variety of texts that mobilize this movement, including fiction, poetry, memoir, scholarly works, drama, popular media and films. We will consider voices from the "global south," non-Western countries that are speaking back to the economic and political centers of globalization. Pairing analysis with these texts with some examples of praxis, or political practice, we will think through and debate how critiques of power can move toward social change. Students will be encouraged to use these texts and a series of shorter writing assignments about texts to build toward a final project relevant to their own discipline. Readings might include Kimberl and #233; Crenshaw, Audre Lorde, bell hooks, Roxane Gay, Chimamanda Ngozi Adichie, Mona Eltahawy, Erika L. S and #225;nchez, Chandra Talpade Mohanty, Fatima Mernissi and Mari Matsuda, Fatima Mernissi, and Aiwah Ong.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-338 Internship Mini

Intermittent
This course is designed to help you explore possible writing-related careers as you gain workplace experience and earn academic credit. You'll work on- or off-campus as an entry-level professional writer in a field of interest to you (public relations, journalism, advertising, magazine writing, non-profit, healthcare, etc.). You are responsible for finding an internship. Most of your class time for the course will be completed at your internship site. As the academic component of the course, you'll keep a reflective journal and meet periodically with the internship coordinator to discuss your internship and related professional issues. You must register for the course before the add/drop deadline of the semester in which you want to do your internship. Before you can register, you must contact the internship instructor listed above to express your interest in the course and to be cleared for registration. Credit for the internship course cannot be retroactively awarded for past internships.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-339 Topics in Film and Media

Intermittent: 9 units
Topics very by semester and section. For Fall 2023 section descriptions, visit the course URL.
Prerequisites: 76-101 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

Course Website: https://docs.google.com/spreadsheets/d/1HzTjLjBFM73kSJver61zYwMb2GfFYzS7zFdxzMyH6Ig/edit?usp=sharing (https://docs.google.com/spreadsheets/d/1HzTjLjBFM73kSJver61zYwMb2GfFYzS7zFdxzMyH6Ig/edit/?usp=sharing)

76-340 Hospitable Worlds: Migration and Settlement on Earth and in Space

Intermittent: 9 units
Are you an artist, writer, designer, science major or film major who has ever thought about living on Mars? Do you watch sci-fi movies and think, "whoa, that looks cool," or "no way, that's not how it would work!" Do you worry about climate change on planet Earth, and think about how to use your creativity to imagine a better future? This class invites students in the visual/literary arts and the sciences to explore planetary hospitality. With each passing year, climate change makes our planet less hospitable for human life. As concerns about Earth's climate grow and the costs of space travel shrink, there has been renewed interest in establishing settlements in outer space. The goal of this class is to explore both the diminishing hospitability of our planet and the prospects of hospitality on others. We will investigate these themes through a variety of media (written, visual, auditory, etc.) and use the questions/themes of the course as inspiration for creating collaborative artistic productions incorporating art and media of all kinds (sketches, poems, paintings, videos, music, etc.).
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-341 Race & Gender in the Age of Jane Austen

Intermittent: 9 units
From Bridgerton (Netflix) to Sanditon (ITV), there is a current boom in Regency adaptations that practice "colorblind" or "color-conscious" casting while interrogating the period's gendered and racial dynamics. But how were race and gender, and their intersections, actually forged and navigated in the age of Austen? This 300-level course will look at Romantic-era in both a historical and a contemporary context. Through reading, viewing, and graded assignments including short essays and oral presentations, we will practice methods for analyzing the formal features of literary and visual texts, such as the structure of a novel, the rhythms of poetry, or the costuming of period drama. In doing so, we will ask: how do these texts respond to historical phenomena such as empire, the rights of women, and slavery and abolition? How and why do contemporary adaptations take up these questions? Examples of readings include Aphra Behn's Ooronoko, Jonathan Swift's "The Lady's Dressing Room," Jane Austen's Mansfield Park, Mary Prince's The History of Mary Prince, and William Wordsworth's "To Toussaint L'Ouverture."
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-342 Love: A Cultural History

Spring: 9 units
This is a course about the cultural history of love. We will focus on romantic love, with an emphasis on how ideas about love have been a dynamic part of our social, political and economic world. Some of the questions to be addressed include: How, historically, did the idea of love become coupled with freedom? How did romantic love come to be considered the epitome of self-fulfillment and what are the problems with that idea? How has the idea of romantic love been mobilized on behalf of things like the state, the nation, capitalism or revolution? How do types of love function as a measure of belonging or deviance? How does the discourse of love enter different kinds of institutional arrangements, such as marriage or state citizenship? As a way to explore these questions, this course looks primarily to literature, including fiction, poetry, and drama, but also to philosophy, history, anthropology, sociology and law. Students will immerse themselves in an interdisciplinary range of material as they read, discuss and write about these representations. We will roam through cultural theory of affect, psychoanalytic notions of love, historical constructions of marriage, and feminist discussions of love and sexuality. Possible texts include works by William Shakespeare, Jane Austen, Toni Morrison, Arundhati Roy and Ocean Vuong.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-107) or (76-106 and 76-108)

76-343 Rise of the American Novel

Intermittent: 9 units
This course will survey American fiction from the beginning of the nation through the first half of the twentieth century. We will look at early fiction, like Washington Irving's "Rip Van Winkle" and mid-1800s classics like Hawthorne's Scarlet Letter, up to twentieth-century works like The Great Gatsby and perhaps some contemporary novels. Through the term, we will ask how the fiction represents the special character of American experience. Alongside readings, you will write several short papers and present some of your research to the class.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-347 Major Fiction

Intermittent: 9 units
We read newspapers for news about our world. But we also read fictionnovels and storiesto tell us about how it feels to live in the world. Sometimes they are like our world, and sometimes very different. In this course we'll read fiction that offers realistic portraits of 19th century society, like Charles Dickens' Great Expectations or Anne Bronte's The Governess, alongside more fantastical portraits like "Rip van Winkle" or contemporary scifi. We will sample fiction from the 19th through the 21st century to trace the course of fiction from romance to realism through modernism to contemporary genre, like dypstopian masterpieces like Station Eleven or Severance. We will also consider about what they say about their culture and society.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-107) or (76-108 and 76-106)

76-349 Climate Fictions

Intermittent: 9 units
During the last 20 or so years, a new kind of fiction has emerged responding to scientific models of climate change. Climate fiction, or "cli-fi," most often imagines a future in which nothing has been done or done soon enough to limit global warming. Much of this literature fits into the broad genre of science fiction, but some of it uses other fictional modes, including realism and postmodernism. This course will look at a variety of fictional approaches to climate change, including a few in visual media. We will consider why fiction is a necessary component of our understanding climate changecomputer models are fictions of a sortbut also whether and how fictional narratives such as novels and films can help motivate action. We may also read some earlier narratives of environmental catastrophe, and some nonfictional discussions of climate change. Likely authors include Amitav Ghosh, Margaret Atwood, Barbara Kingsolver, Kim Stanley Robinson, and Richard Powers.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

76-350 Critical Theories about Literature

Intermittent: 9 units
This course studies the long-debated problem of how readers or spectators respond to texts (in print, performances, film, or painting) from ancient rhetoric and tragedy to contemporary mass culture.We will read in a range of critical theories, from thinkers like Aristotle, Plato, and Longinus to recent theorists in poststructuralism, gender studies, Marxism, and affect theory. How have such critics and theorists thought about the nature of the text and of representation and #8212;or the relation of authorship to reading, ideas, and affects? What techniques of analyzing literary texts have such theories stimulated? Two papers and vigorous in-class discussion will be required.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-351 Rhetorical Invention

Intermittent: 9 units
Rhetorical invention is a discursive approach to the process of inquiry, discovery, and problem solving, or how we decide what to say, what arguments to advance, and what means of persuasion to use in any situation. In other words, it is a rhetorical approach to content generation in any speaking or writing situation. Although invention is centrally important to rhetoricwithout it rhetoric becomes a superficial and marginalized study of style and arrangementfrom the Scientific Revolution and Enlightenment through the mid-twentieth century invention all but disappeared as a topic of rhetorical study, influenced by the view that the content of communication should be exclusively governed by deductive logic and the scientific method rather than rhetorical considerations such as audience, situation, or the history and figurality of language. This repudiation of rhetorical invention fundamentally shaped modern thought and continues to influence the ways we think and communicate today. In this course, we examine the status of rhetorical invention in the development of modern thought and then attend to scholarly efforts to revive a rhetorical understanding of invention from the mid-twentieth century forward, surveying contemporary theories of rhetorical invention including those promoted by postmodern, posthuman, and digital rhetorics. The course is designed to explore the central importance of invention to contemporary rhetorical theory through a pairing of historical and contemporary readings. In addition to regular reading responses, students select a research project examining the history or theory of rhetorical invention.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-353 Transnational Feminisms: Fiction and Film

Intermittent: 9 units
How do controversial practices related to women become touchstones that draw women together across cultures or, conversely, push them into separate cultural and political spheres? This introductory-level course familiarizes students with the challenges transnational feminism has posed to Western notions of feminism. To explore these contestations, we will look at a series of controversies. We will read these controversies through novels, drama, short stories and films, with some secondary theoretical readings. This course will take six case studies concerning cultural practices that have generated global debates about the status of women and issues like consent, freedom, and equality. Beginning with several works about regional/Islamic practices of veiling, we will look specifically at the close connections made between womens practices and elements of tradition, including religion. With an eye toward historicizing feminist interventions, we will look at 19th century debates on sati, commonly called widow burning, in India, to see how certain issues became loci for global intervention during colonial periods and, later, for global feminist movements. Within the contemporary period, we will turn to cultural, economic and political practices like female genital cutting, transnational domestic labor, global sex trade, and transnational forced marriage. For each of these controversies, we will be reading a range of positions represented in different types of writing across genre, with a focus on literary and filmic depictions.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-354 Watchdog Journalism

Intermittent: 9 units
The practice of journalism involves covering the news of the day. Investigative journalism uncovers it, digging through public records and data to expose corruption or correct social injustices. The process takes patience and persistence, as well as familiarity with right-to-know laws, to find that gold nugget of information that exposes secrets or becomes the missing piece to a larger puzzle. In this course, students will learn investigative techniques that make the powerful accountable, using government documents, financial filings and databases to spot undetected crime patterns, an unfair housing policy or perhaps questionable spending by a non-profit charity. Investigative journalism has a storied history of exposing wrongdoing and today many of the tools historically used to tell those stories are available to everyone. This course will help budding journalists, researchers and anyone else interested in addressing societal problems find those tools and learn how to use them. This course meets the Dietrich College Deciding Gen Ed requirement.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-357 Linguistic & Social Aspects of Immigration

Intermittent: 9 units
This course introduces students to the linguistic and social aspects of immigration in today's global society. Immigration will be studied as a socio-political construct with an emphasis on the linguistic, socio-cultural, and political challenges and opportunities that migration creates for the individual and society. Throughout the course we will explore one key question: What challenges and opportunities do different aspects of migration posses for multilingual societies and individuals? A great deal of the course focuses on the linguistic challenges that migration creates for the individual and society, with a special emphasis on the development of bilingualism and the education of immigrant children. From a larger socio-political perspective, the course focuses on various case studies of immigrant populations throughout the world in order to obtain a better understanding of the characteristics, opportunities, and challenges faced by immigrant populations internationally.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-358 Making the Documentary

Spring: 9 units
Making The Documentary This will be an experimental one-of-a-kind course where students will be working alongside an experienced film director while taking part in a hands-on documentary project from concept to finished product. This course will explore the filmmaking process from concept and development through to production and postproduction with the intention of completing a feature documentary. The documentary subject this semester will focus on artists, journalists, filmmakers and writers who are living in exile from their home countries. In many places around the world, oppressive regimes still do not respect the right to freedom of expression. Artists resisting oppression sometimes have no other choice than to abandon their countries. Their engagement continues abroad in safer countries, where they can continue to create politically-infused art. The documentary project will focus on several exiled artists living in Pittsburgh in collaboration with the City of Asylum, the world's largest sanctuary for writers and artists living in exile. Our focus will be to reveal the existential creativity and the role of these artists in a time of crisis. Students will be required to engage in concept development, researching, producing, and editing through to final distribution. Students will take part in organizing and ordering the footage, choosing screen selects, creating rough cuts, and fine cuts in order to find the heart of the documentary. Pick-up shoots, B-roll, archival material, music, and sound design will also be considered as needed.
Prerequisite: 76-292

76-360 Literary Journalism Workshop

Intermittent: 9 units
S23: How can storytelling and reading literature help us understand the worlds of healing and illness? We'll read texts focusing on doctors, nurses, patients, caregivers, those living with chronic illness, and disability. Students will write about their own experiences, and those of loved ones.
Prerequisites: 76-262 or 76-261 or 76-270 or 76-271 or 76-472 or 76-372 or 76-265 or 76-260

76-361 Corpus Rhetorical Analysis

Intermittent: 9 units
The Digital Humanities is a huge and growing field spanning many disciplines and skill sets. The focus of this course is on tools and methods that allow students to analyze textual corpora as purveyors of stories, information, and arguments that seek to influence cultural thinking, reveal existing cultural mindsets, and often both in tandem, either synchronically or diachronically. This is the point of view often taken by analysts who work for universities, think tanks and intelligence agencies who seek to understand cultural trends and mindsets from volumes of digital texts. For such analysts, close reading is an indispensable part of their work and computing tools help focus their reading while reading helps refine their understanding of the computer output. The course will give students intensive practice with methods and tools for analyzing corpora of text at the word, phrase, and sentence level, and with working with large scalable dictionaries and multivariate statistics.
Prerequisites: (76-106 or 76-108 or 76-107 or 76-108 or 76-106 or 76-107 or 76-102 or 76-101) and 76-380

76-362 Reading in Forms: Nonfiction

Intermittent: 9 units
In this reading-intensive course we will analyze and discuss different types of narrative structure, narrative suspense, voice, metaphor, and point of view that make for effective non-fiction writing. We will also examine the difference between good writers and good work, the functions of objective distance from and intimate investment in a subject, as well as the philosophical questions spurred by non-fiction writing. What is the non-fiction writer's role, and how does it differ from that of the fiction writer? Where do the two genres overlap? What gives non-fiction writing integrity? What does the term "creative non-fiction" mean? How have the form and aims of non-fiction writing - from memoir to essays to long-form journalism - evolved for better and for worse? We'll be reading a selection of essays from a variety of writers, as well as full works from a few writers considered masters of the form.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-363 Reading in Forms: Poetry

Intermittent: 9 units
How does identity color our reading or alter our expectations of a poem? How does a poet's identity inform their poetic approach? In this course, we'll shift our focus from poetry to poet, text to context, and back, as we explore how the poet's identity operates both within their work and outside of it. Through class discussion and readings of poetry and essays we'll approach questions of permission, permissibility, responsibility, appropriation, and the identity poetics and politics at play in the evolving landscape of contemporary American poetry.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-364 Reading in Forms: Fiction

Fall and Spring: 9 units
What does it mean to feel at home? In this course, we will read and discuss fiction, memoir, and other creative work that centers on the search for home. We'll expand the idea of home to include not only the desire for comfort in a particular place, but also for a feeling of home in one's body, family, or culture. Expect to read nine or ten books, to write a response paper for each class, and to do one in-class presentation, in which you will lead the discussion. Active participation in discussions is a major part of your course work.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-365 Beginning Poetry Workshop

Fall and Spring: 9 units
In this workshop, we'll explore the building blocks of poetry, as participants develop their eye and ear as poetry readers, and practice different poetic techniques in their writing. Students will read the work of contemporary poets, attend poetry readings, respond to writing prompts, and read and respond to each other's work. Through our reading, discussions, and creative exercises, we'll examine the role of line, line break, shape, sound, silence, rhythm and form in poetry, with an eye toward how craft choices communicate on the page and how they reflect the world of the poet.
Prerequisites: (76-102 or 76-101 or 76-106 or 76-107 or 76-108) and 76-265 Min. grade B

76-367 Fact Into Film: Translating History into Cinema

Intermittent: 9 units
From the very beginning, film has provided a window into the past. But how useful are the images we see through that window? For every person who reads a work of history, thousands will see a film on the same subject. But who will learn more? Can written history and filmed history perform the same tasks? Should we expect them to do so? How are these two historical forms related? How can they complement each other? This course will draw examples from across the history of film in order to examine how the medium of film impacts our understanding of facts and events, the ways that film transfers those facts to the screen, and how that process affects the creation of historical discourse. Films may include such titles as The Fall of the Roman Empire, The Gunfight at the O.K. Corral, Saving Private Ryan, World Trade Center, Enemy at the Gates, Lagaan and Hero.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-368 Role Playing Game Writing Workshop

Fall: 12 units
Role playing games (RPGs) are a vibrant and viable popular medium for interactive storytelling. This workshop builds upon dramatic theory DNA existing in plays, TV and film. Gameplay is performance. The skills developed when creating any time-bound media transfer well to games but must be seen through a different lens - the lens of the player. To do so, we first examine and dissect both RPG story and game design (using pencil and paper examples) seeking an understanding of both game systems as well as narrative best practices. In class we focus our examination on the most popular existing intellectual property (The Lord of the Rings). Students who desire admittance to this class should be at least somewhat familiar with that world to succeed in the class. Each student works on a four-person team to create an original RPG campaign-style adventure for an already existing story world. The final product is a portfolio-quality set of dramatic scenes, epic tabletop encounters, and character sketches. This is not an RPG design course. Any level of writing experience is welcome, BUT experience playing RPGs and #8212; either tabletop or video game and #8212; is a must. Experience as a GM for an RPG is a big plus, and applicants who possess such experience should be sure to let the instructor know in advance.
Prerequisites: 76-269 Min. grade C or 76-260 Min. grade C

76-370 Independent Study in Literary and Cultural Studies

All Semesters
An Independent Study course is a course taken with faculty supervision that goes beyond the courses offered in a particular area of interest. It should not duplicate a course offered in the regular schedule of classes. A student wishing to take an independent study needs to locate a faculty member whose research interests are close to the area of proposed study and meet with the faculty member to discuss whether it is something the faculty member is interested in doing. The department requires that the student and instructor submit a written contract (available in the English Department) detailing the expectations (description of course of study, readings, how often the student/faculty member will meet) and requirements for the completed independent study project (number and amp; length of papers) and a time-line for completion of the work. You should think of this as developing the equivalent of a detailed course syllabus/schedule, and typically involves development of a bibliography of readings.

76-372 News Writing

Fall: 9 units
In this course, we will study and learn the fundamental skills of journalistic writing as well as discuss topics related to how different media outlets cover news. On the writing side, we will start with the basics - the importance of accuracy, clarity and fairness, writing for audience, striving for objectivity, judging newsworthiness, meeting deadlines. The core class work (and most of your grade) will be based on seven writing assignments due approximately every two weeks throughout the semester. Expect to do some writing each class period. We will learn how to write a story lead, how to structure a story and how to write different kinds of news stories, from crime news to features to editorials and commentary. We also will learn how to research a news story, conduct an interview and sort through mountains of information to discern what's important so we can write about it in a clear, concise manner.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-373 Argument

Fall and Spring: 9 units
This course introduces the fundamentals of argumentation theory and offers guided practice in analyzing and producing arguments. Through analysis, we will learn what an argument is, how to identify one, and what the names and functions of a variety of argument features are. We will also explore the production of argument by pursuing the questions: What are my argumentative goals? How do I build a theory of my audience? What means of persuasion are available for me to achieve my goals? And how should I order the contents of my argument? To answer these questions, we will explore argument in a variety of genres including visuals, op-eds, presidential speeches, and congressional testimonies.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-374 Mediated Narrative

Spring: 9 units
We are offering the opportunity to travel into the future, build it, and represent it in creative and critical ways. The Mediated Narrative: Futuristic Explorations course aims to explore the concept of the future, analyze its representations, and create a media project based on potential utopian/dystopian areas of human progress and evolution. Students will have to recreate and represent their own visions of the future through a media project. Essential to the research and development of the class is the concept of humanity and empathy within a technological social world. Ideas such as: "reality ahead of schedule"; "high tech, low life"; "neon and corporate dystopias"; "cyberpunk"; "post-human"; "sustainability"; etc, will be analyzed and discussed in class. Concepts of civilization, the cityscape, the individual, the body and the mind will be examined as we have seen technology and society evolve. During the 2024 spring semester there will be two onsite visits to historical places that under similar idealist social premises of the future have embodied diverse existential outcomes: a) The city of Arcosanti in the Arizona dessert b) The Old Economy Village in Pennsylvania. Both places represent a utopian philosophy of life which attempted to be in synchronicity with everyday life. The idea is to map traditional futuristic themes and styles and find new ways to represent them based on the needs and contradictions in our present world.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-376 Crafting Race in 19th-Century Britain

Intermittent: 9 units
This course explores how the idea of race was developed, deployed, and reinforced through nineteenth-century British culture, from novels to museums to ballet. Students investigate how literature and art produced and replicated arguments about race that justified or fought against oppression. Alongside literary texts, students will also work with advertisements, paintings, filmic adaptation, and theatrical practice. We take an intersectional approach, thinking not only about race, but also the connections between gender, class, sexuality, and disability. What are the roots of problems we think of as modern, like whitewashing in media? How has racial thinking been passed down through time and across oceans? Ultimately, our investigation aims to provide insight to modern issues of race through a better understanding of cultural history. Note: we will have one field trip during class time (Carnegie Museum of Art and Natural History)

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-377 Shakespeare on Film

Intermittent: 9 units
The dramatic works of William Shakespeare have inspired an extraordinarily rich and varied corpus of films that includes legendary performances, adaptations from across the full breadth of world cinema, and experiments in every major genre. This course will consider a selection of key Shakespeare films alongside critical readings centered on questions of authorship, adaptation, technology, and performance. As we watch, read, write, and converse together, we will work toward a broader understanding of what Shakespearean drama means in a 21st century context and how film has helped to shape Shakespeare's unparalleled cultural influence.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

76-380 Methods in Humanities Analytics

Spring: 9 units
The computer-aided analysis of text has become increasingly important to a variety of fields and the humanities is no exception, whether in the form of corpus linguistics, stylometrics, "distant reading," or the digital humanities. In this course, we will build a methodological toolkit for computer-aided textual analysis. That toolkit will include methods for the collection data, its processing via off-the-shelf software and some simple code, as well as its analysis using a variety of statistical techniques. In doing so, the class offers students in the humanities the opportunity to put their expertise in qualitative analysis into conversation with more quantitative approaches, and those from more technically-oriented fields the opportunity to gain experience with the possibilities and pitfalls of working with language. The first part of the term will be devoted to introducing fundamental concepts and taking a bird's eye view of their potential application in domains like academic writing, technical communication, and social media. From there, students will initiate projects of their own choosing and develop them over the course of the semester. The goal is to acquaint students with the strengths and limitations of computer-aided textual analysis and to provide them with the necessary foundational skills to design projects, to apply appropriate quantitative methods, and to report their results clearly and ethically to a variety of audiences. This class requires neither an advanced knowledge of statistics nor any previous coding experience, just a curiosity about language and the ways in which identifying patterns in language can help us solve problems and understand our world.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-384 Race, Nation, and the Enemy

Intermittent: 9 units
Conflicts over racial and national identity continue to dominate headlines in the United States as they often have during the nation's history, from debates regarding the immigration, naturalization, and birthright citizenship of racial minorities to debates regarding racial disparities in access to civil rights. This course explores the discursive practices through which racial and national identities are formed and the frequent conflicts between them, particularly by focusing on the role of enemies, threats to the nation, and sacrifices made on behalf of the nation in American public discourse. Alongside primary sources of public discourse regarding wars, the immigration and citizenship of racial minorities, racial segregation and civil rights, and the criminal prosecutions of dissidents during periods of crisis, we will read secondary sources offering multiple theoretical and disciplinary approaches to the study of racial and national identity formation. Along with regular brief responses to readings, assignments will include a short rhetorical analysis paper and a longer research paper.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-107) or (76-108 and 76-106)

76-385 Introduction to Discourse Analysis

Intermittent: 9 units
"Discourse" is language: people talking or signing or writing. Discourse analysts ask and answer a variety of questions about how and why people do the things they do with language. We study the structure of written texts the semi-conscious rules people use to organize paragraphs, for example as well as the unconscious rules that organize oral discourse such as spontaneous stories and arguments. We study how people signal their intended audience-interpretations of what they say as foreground or background information, a casual remark or solemn promise, more of the same or change of topic. We look at how grammar is influenced by what people need to do with language, and how discourse affects grammar over time. We ask how children and other language learners learn how to make things happen with talk and writing. We ask how people learn what language is for, from exchanging information to writing poetry to perpetuating systems of belief. We analyze the choices speakers and writers make that show how they see themselves and how they relate to others. (Choices about how to address other people, for example, both create and reflect relationships of power and solidarity). We study how people define social processes like disease, aging, and disability as they talk about them, and how language is used to mirror and establish social relations in institutional settings like law courts and schools as well as in families and among friends. This course touches on a selection of these topics and gives students practice in analyzing the complex nuances of language. The course is meant for anyone whose future work is likely to involve critical and/or productive work with language: writers and other communication designers, critics who work with written or spoken texts, historians, actors, sociologists, and so on.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-107 and 76-108) or (76-108 and 76-106)

76-386 Language & Culture

Intermittent: 9 units
This course is an introduction into the scholarship surrounding the nature of language and the question of how language shapes and is shaped by social, cultural and political contexts. We will begin by studying important literature in linguistics and language theory, both to introduce us to how scholars think about language and to give us a shared vocabulary to use for the rest of the semester. We will then move into case studies and theoretical works exploring the intersections of language use, individual and group identities, and the exercise of power, in its many forms. In particular, we will focus on the relationship between language and culture by asking, in what ways does language influence and constitute social change? How is social change reflected by changes in the way we use language? Over the course of the semester, you will work on applying the knowledge and theoretical tools you gain to your own analysis of a linguistic artifact that you choose.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-108 and 76-106)

76-387 Writing in the Disciplines

Intermittent: 6 units
This mini will introduce you to the theory and practice of writing instruction in contexts outside of English studies. We will learn about the distinction between Writing across the Curriculum and Writing in the Disciplines and challenges to providing integrated, high quality writing instruction across the university. We will explore the implications of the wide variety of forms of academic writing for instruction in English classrooms, including high school and first-year writing classrooms. Assessments will include reading responses and a final paper reviewing research on writing in a specific writing context of your choosing. Students enrolled in the course for six units will be expected to do additional readings and give an oral presentation. Please note that in terms of time commitment, a 3-unit mini will require approximately six hours per week (three hours homework and three hours class meetings) and a 6-unit mini will require twelve hours per week.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-107 and 76-108) or (76-108 and 76-106)

76-388 Coding for Humanists

Intermittent: 9 units
This course provides students with the foundational knowledge and skills to develop and/or utilize computer-aided research tools for text analysis. Through a series of hands-on coding exercises, students will explore computation as a means to engage in new questions and expand their thinking about textual artifacts. This course is designed for students with no, or very little, coding experience. So, if you have already taken a programming course, this course is most likely not for you. Students who have taken 15-110 and/or 15-112 may not take this course. For the final project, you will develop a small research project involving a computational analysis of a corpus of texts. You will plan, design, and write a computer program that processes and analyzes a textual corpus of your choice. Students who are taking the course for 9-unit will write a brief project report (3-5 pages) that summarizes your final project. Graduate students in the MA in Rhetoric/PhD programs must register for 12-unit, and will complete a research paper (4,000-5,000 word).
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-389 Rhetorical Grammar

Fall and Spring: 9 units
This is a course in fundamental grammatical structures of English and how these structures fit into the writer's toolkit. This means you will learn a lot about English-language grammar in this course en route to understanding a lot about English language writing. This course is designed for MA students in professional writing and undergraduates who want to improve their grammar, their writing, and their depth of understanding of how improvement in grammar impacts improvement in writing.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-390 Style

Fall and Spring: 9 units
This course teaches you how to write clearly. Specifically, the principles you learn in this course will help you 1) to clearly represent actions and the characters responsible for them; 2) to make your paragraphs coherent and cohesive; 3) to write sentences that stress important information; 4) to cut unnecessary prose; and 5) to reshape lengthy sentences so as not to perplex your reader.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-107) or (76-108 and 76-106)

76-391 Document & Information Design

Fall: 9 units
This course provides students who have already learned the foundation of written communication with an opportunity to develop the ability to analyze and create visual-verbal synergy in printed documents. Students will be introduced to the basic concepts and vocabulary, as well as the practical issues of visual communication design through a series of hands-on projects in various rhetorical situations. Assigned readings will complement the projects in exploring document design from historical, theoretical, and technological perspectives. Class discussions and critiquing are an essential part of this course. Adobe InDesign, Photoshop, and Illustrator will be taught in class, and used to create the assigned projects.
Prerequisites: 76-390 or 76-270 or 76-271

76-392 Special Topics in Literature & Culture

Intermittent: 9 units
Topics vary by semester. See course URL for details.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

Course Website: https://docs.google.com/spreadsheets/d/1U81b4BSF0aij6u_zYq39Uf7q2ZTiqqAQaOIJ9V2LhnA/edit?usp=sharing (https://docs.google.com/spreadsheets/d/1U81b4BSF0aij6u_zYq39Uf7q2ZTiqqAQaOIJ9V2LhnA/edit/?usp=sharing)

76-395 Science Writing

Spring: 9 units
You will learn how to write clear, well-organized, compelling articles about science, technology and health topics for a general audience. You will learn how to carry out research on scientific topics using primary and secondary sources, how to conduct interviews, and how to organize that information in a logical fashion for presentation. For writing majors, the course will increase their understanding of scientific research and how to describe it accurately and in a compelling manner to a general audience. For science majors, this course will teach them how to craft fluid, powerful prose so that they can bring their disciplines to life. The course is not intended just for those who want to become science writers, but for anyone who may have the need to explain science, medicine, or technology to a general audience, whether it is an engineer describing a green building project at a public hearing or a computer programmer describing new software to a firm's marketing staff. Scientists and educators today are increasingly concerned about the public's lack of understanding about scientific principles and practices, and this course is one step toward remedying that deficit. You will get a chance to read several examples of high-quality science writing and interview researchers, but the primary emphasis will be on writing a series of articles, and rewriting them after they've been edited. Your assignments will range from profiles of scientists to explanations of how something works. In particular, this year's class will focus on how science and society interact, whether that means the way that science writers write about public health and the COVID pandemic or climate change. The class will be run partly as a writing workshop where students will be organized in teams where they will discuss ideas, as well as edit and critique each other's work in class, in a process similar to what journalists routinely go through.
Prerequisites: (76-108 or 76-106 or 76-107 or 76-101 or 76-102) and (76-372 or 76-270 or 76-271)

76-397 Instructional Text Design

Intermittent: 9 units
This course focuses on the planning, writing, and evaluating of instruction of various kinds, especially instructional texts. It is particularly appropriate for professional and technical writers, but also a good option for anyone interested in fields that involve substantial instruction, such as teaching or employee training. In the first part of the course, we'll examine the recent history of instructional design and the major current theories. Then we'll take a step back and study the concepts of learning upon which these theories are based, with particular attention to their implications for how instruction is structured. You'll find that different learners (e.g., children, older adults) and goals (e.g., learning concepts and principles, learning to apply principles to solve novel problems, learning a procedure, learning to change one's behavior, etc.) require different types of instruction.
In the second part of the course, we'll look in detail at models of how people learn from texts and what features (e.g., advanced organizers, examples, metaphors, illustrations, multimedia) enhance learning under what circumstances. We will study and analyze particular types of texts. Some possible examples include an introduction to the concept of gravity; a tutorial for computer software; a self-paced unit in French; adult educational materials in health care; a workshop on sexual harassment in the workplace; or a unit to train someone how to moderate a discussion. We will also look at various methods (concept mapping, think-aloud, comprehension tests, etc.) that are used to plan and evaluate instructional text. You will do a project, either individually or in a small group (2-3), in which you design, write and evaluate instruction.
Prerequisites: 76-271 or 76-270

76-401 Hollywood vs. the World

Intermittent: 9 units
For almost a century the American film industry has dominated popular media worldwide. Anywhere in the world, American stars, American films, and American modes of storytelling are never far away. Why and how was that dominance achieved, and how have other cultures and industries challenged it? Film and television account for billions of dollars of U.S. exports and provide one of the key sources of global "soft power" and cultural influence. Understanding how that dominance works is therefore crucial to the question of America's economic, political and cultural place in the world. This course will examine ways in which other national cinemas have fought, or are currently fighting, against the hegemony of American popular film culture, and the ways in which the American film industry has maintained its dominant position in world markets for nearly a century.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-407 Topics in Literary & Cultural Studies

Intermittent: 9 units
Topics vary by semester. Spring 2022: There Are Black People in the Future. In 2018 the African American artist and CMU professor, Alisha Wormsley created a slogan for a billboard in Pittsburgh's East Liberty that read: THERE ARE BLACK PEOPLE IN THE FUTURE. The billboard had featured many artists and slogans over a period of years, but this one was taken down when the building's landlord objected to the content. The controversy over this piece of art gives this course its name. There are black people in the future, and there are extraordinary black artists in Pittsburgh at this very moment. This special topics course will consider what some are calling a new Pittsburgh Renaissance in the black arts, from art to literature to film and music. Featured writers include Deesha Philyaw, The Secret Life of Church Ladies, Brian Broome, Punch Me Up To The Gods, and Damon Young, What Doesn't Kill You Makes You Blacker. We will also look at the work of the writer Jason England, the artists Alisha Wormsley, Vanessa German, Devan Shimoyama, the rapper Jasiri X, and the film maker Chris Ivey. An in depth look at these artists will be paired with an examination of the history of African Americans in Pittsburgh, and current economics, sociology and politics surrounding race in the city.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-107 and 76-108) or (76-106 and 76-108)

76-408 Culture and Globalization

Intermittent: 9 units
We are often told we live in a period of globalization, but what that means differs widely. Theories of globalization describe such diverse processes as international capital and markets, neo-liberalism and neo-colonialism, environmental devastation, transnational labor and migration, modernity, shifts in spatial and temporal relations, cosmopolitanism, global cultural production and consumption, and the resurgence of nationalism. In this course we will explore and historicize the concept of globalization from both a global literary perspective and an interdisciplinary lens. Pairing literary works from around the world with scholarship from sociology, political science, gender and critical race studies, and anthropology, we will examine the contradictions, conflicts and possibilities of associated changes in the world. We will investigate the role of representation and aesthetics by considering the work of literary writers as well as some filmmakers, journalists and activists. The course will be organized as a series of topical foci that might include neoliberalism and labor, the local and the global, environmental changes, secularism and tradition, the globalization of feminism, and global migration and border control.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-410 The Long Eighteenth Century

Intermittent: 9 units
Angela Davis wrote that "freedom is a constant struggle": how do the freedom struggles of the long eighteenth century continue into the present? How were "modern" categories of race and gender forged and navigated in the long eighteenth century? In this course, we will study literature and culture between roughly 1660 and 1820, an era in which historical phenomena such as European empires, the Rights of Woman, and slavery and abolition coincided with changes in print and media culture to produce profound cultural changes that are still with us. Through reading, discussion, and graded assignments including short essays and oral presentations, we will examine the interanimating relationship of literature and history in moments of crisis. Examples of primary readings include Aphra Behn's Ooronoko, selections from Milton's Paradise Lost, Jane Austen's Mansfield Park, Mary Prince's The History of Mary Prince, and William Wordsworth's "To Toussaint L'Ouverture." Secondary readings will draw from a variety of critical traditions such as post- and de-colonial studies, Black studies, post-structuralism, and material culture studies.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-414 Decolonial Imaginaries

Intermittent: 9 units
TBD
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-107) or (76-108 and 76-106)

76-415 Mediated Power and Propaganda

Intermittent: 9 units
For most of us, the word "propaganda" triggers a familiar script. We tend to think of totalitarian regimes where the State controls information and prohibits the expression of dissenting views. We also tend to associate propaganda with certain rhetorical techniques - highly emotional words, deceptive representations, and glittering generalities that inhibit rational thought and manipulate public opinion. According to such popular views, propaganda is linked to the dissemination of false information and is antithetical to the norms of democratic society. Our class will challenge these assumptions. First, instead of confining propaganda to authoritarian governments, we will examine how propaganda functions within democratic society. Indeed, we will focus on domestic propaganda in America, especially political propaganda but also propaganda in advertising and public relations. Next, instead of focusing exclusively on deceptive rhetorical techniques, we will ask a more elemental question: What enables propaganda to circulate? Answering this question will force us to consider the routines and values of corporate media as well as the power relations that give some people special access to channels of mass communication. Certainly, we will also examine propaganda messages themselves, attending to manipulative tactics as well as rhetorical strategies used to induce uptake in the mainstream press. We begin our seminar by studying key theories of propaganda, looking at primary texts for various definitions and criticisms of the concept. We will then examine how powerful institutions, especially media organizations, manage the dissemination of propaganda in democracies. Finally, we will consider how to analyze propaganda, generating methodological prerequisites for scholarly study. Ultimately, students will have the opportunity to conduct their own research on propaganda as it relates to their academic and professional goals.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-416 Rhetorics of Race & Empire

Intermittent: 9 units
The construction and enforcement of racial hierarchies has been a central phenomenon in empire-building around the world. This class takes as its main focus the relationship between imperialism and race, especially in, but not limited to, the United States. How has the U.S. justified imperial expansion around the world-military, economic, and cultural? How have its actions triggered the movements and migrations of populations, and how have those movements and displacements been explained? What cultural shifts around racial meanings have occurred, here and abroad, as a result of U.S. imperialism? How has the role of the U.S. in relation to the rest of the world, particularly peripheries and the global South, been narrated? We will take a special interest in the role of language in constructing and perpetuating racial meanings in the context of empire, and in the everyday communicative practices that both shape and have been shaped by imperial impulses. Students will learn to think critically about the presence of such discourses in everyday life, and produce a final paper or project analyzing a narrative of their own choosing in which race and empire intersect.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

76-418 Rhetoric and the Body

Intermittent: 9 units
This course offers an introduction to rhetorical studies of the body and is centered on the following three questions: What is the role of the body in rhetorical theory? What role does rhetoric play in constructing the body as a raced, gendered, dis/abled, cultural, fleshy, and political entity? And, how might moving, feeling bodies challenge, regulate, or disrupt these rhetorical constructions and furthermore, our theories of rhetoric? Our readings will explore the role of embodiment in rhetorical theory, examining a number of contemporary and historical theories of the body. In the process, we will explore how to put rhetoric and the body into conversation with one another and what methodological implications this conversation has for rhetorical studies more broadly. The goal of this course is to provide breadth rather than depth, with the assumption that most students, even those relatively familiar with body and/or rhetorical theory, will approach rhetorical studies of the body as novices. Students will conduct their own research on a topic related to rhetorical studies of the body that also aligns with their professional and academic goals. Graduate students interested in research will benefit from this course's focus on theory and the professional genres central to rhetorical studies. Undergraduates students (both majors and non-majors) will have the opportunity to examine how the body intersects with communication and writing contexts in their everyday public and professional lives. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-423 Transnational Feminisms

Intermittent: 9 units
How do controversial practices related to women become touchstones that draw women together across cultures or, conversely, push them into separate cultural and political spheres? This course introduces the challenges transnational feminism has posed to Western notions of feminism. To explore these contestations, we will look at a series of controversies. This course will take six case studies concerning cultural practices that have generated global debates about the status of women and issues like consent, freedom, and equality. Beginning with several works about regional/Islamic practices of veiling, we will look specifically at the close connections made between women's practices and elements of tradition, including religion. With an eye toward historicizing feminist interventions, we will look at 19th century debates on sati, commonly called widow burning, in India, to see how certain issues became loci for global intervention during colonial periods and, later, for global feminist movements. Within the contemporary period, we will turn to cultural, economic and political practices like female genital cutting, transnational domestic labor, global sex trade, and transnational forced marriage. For each of these controversies, we will be reading a range of positions represented in different types of writing across genre, including scholarly writing, legal cases, media debates, films and literature.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

76-424 Theories of Social Class

Spring: 9 units
How do we define social class? And how do we define popular culture? And what is the relationship between the two? In this class we'll try to answer these questions by looking at the history of class identity in the US, the rise of staggering inequality in the 21st century, and what Newman calls the "labor theory of culture," juxtaposed against the "commodity theory of culture." Texts for the course will include: White Trash: The 400 Year Untold History of Class in America, Robert Reich's documentary Inequality for All, the Oscar winning film Parasite, Netflix's TV series The Maid as well as readings from Marx/Marxist influenced cultural theory.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-425 Rhetoric, Science, and the Public Sphere

Intermittent: 9 units
In the 21st century science and technology are ubiquitous presences I our lives. Sometimes these phenomena spark our imagination and affirm our confidence in a better future. In other instances, they create fear and generate protests over the risks new technologies and scientific ideas pose to prevailing social, cultural, economic, and political orders. In this course we will examine the complex dynamics in the relationships between science, technology, and society. Towards this end we will engages with questions such as: How do we decide who an expert is? To what extent do scientists have an obligation to consider the social and ethical consequences of their work? Is public education about science and technology sufficient for addressing social concerns about risk and controversial scientific ideas? We will grapple with these and other questions by exploring public debates including conflicts over global warming, vaccinations, and the AIDS crisis. With the help of analytical theories from sociology, rhetoric, and public policy, we will develop a framework for thinking about argument and the dynamics of the relationship between science, technology, and the public. We will also look to these fields for tools to assess public debate and to complicate and/or affirm prevailing theories about the relationship between science and society.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-429 Introduction to Digital Humanities

Intermittent: 9 units
This course is a "learn by doing" introduction to questions and methods in digital humanities, with special emphases on common tasks in digital history, digital literary studies, library science, and cultural analytics. Students will likely partner with a national humanities organization to tackle real-world humanities problems while developing core computational competencies such as those required for gathering data (text mining, APIs), transforming data (OCR, regular expressions, natural language processing, image magick), file management (shell commands), data visualization (matplotlib, arcGIS), and more. This course is for juniors and seniors.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-431 Gender Play in Early Modern Drama

Intermittent: 9 units
The playhouses of early modern London offered access to an astonishing spectacle that would be difficult to find anywhere else in the city: men dressed as women, skillfully reproducing (but also exposing, interrogating, and refining) the significations that structure concepts of gender difference. In addition to this fundamental condition of performance and theatrical experience, the plots of the plays themselves regularly engaged with issues pertaining to gender and sexuality, an interest that runs through the raunchy satires performed by companies of adolescent boys, the innumerable comedies of cross-dressing and mistaken identity, and the equally numerous tragedies centered on problems of inequality and imbalances of power. This course will consider a wide range of drama from the period alongside a selection of readings in sexuality and gender theory, thus bringing early modern dramatists such as William Shakespeare and Thomas Middleton into conversation with contemporary thinkers such as Judith Butler and Sarah Ahmed. The body of core texts will include Twelfth Night, The Merchant of Venice, As You Like It, The Roaring Girl, The Taming of the Shrew, The Tamer Tamed, The Island Princess, The Witch of Edmonton, The Silent Woman, Women Beware Women, and Galatea. Please note: First-year students are prohibited from registering for this course. Sophomore students must obtain instructor permission.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-107) or (76-106 and 76-108)

76-434 Literature & Social Change in the 19th Century

Intermittent: 9 units
From the French Revolution to the Victorian era, literature began to play an explosive role in the forces of political transition and the struggle for social justice. This course studies novels, poetry and prose in relation to both political and industrial revolutions during the rise of empire and capitalism and the road to climate change. We will study apocalyptic novels like Mary Shelley's The Last Man and novels of empire like Jane Eyre and its retelling in Wide Sargasso Sea; poetry about living in revolutionary times by Wordsworth and Phillis Wheatley Peters; and anti-slavery writing such as Ottobah Cugoano's "Thoughts and Sentiments on the Evil of Slavery." Secondary readings for graduate students will draw from a variety of critical traditions such as critical race studies, environmental studies, gender studies, postcolonial studies.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-437 Global Realisms:

Intermittent: 9 units
In the standard history of the novel, the genre emerges in distinction from earlier narrative romances as a form bounded by a greater fidelity to ordinary life. In the nineteenth century, this general tendency is further specified in new narrative strategies and subject matter that define realism, which according literary historians, becomes identified with the novel per se. The standard history also insists that realism, while dominant in the 19th century, becomes a residual form in the 20th, replaced first by modernism, then postmodernism. In global/postcolonial fiction, ludic form, especially magical realism, becomes an important standard bearer of progressive politics in the mid20th century, again perceiving realism as residual. This course interrogates that history by looking again at classic realist texts from France and England, reading them in conjunction with novels from the U.S., India, the Caribbean, and Africa, by charting uneven development of forms and richer modes of reading. We will explore the continued importance of realist fiction and the ways it changes across time by placing it in a global context. Likely authors: Balzac, Zola, George Eliot, Joyce, Adiga, Adichie, Updike, Petry, and Semb and #232;ne. Theoretical/critical writings: Woolf, Barthes, Jameson, Luk and #225;cs, Howells, Zola, Brecht, Bloch, and others.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-439 Seminar in Film and Media Studies

Intermittent: 9 units
Topics vary by semester. Fall 2023: Novelistic Television - Topics vary by semester. Fall 2023: Novelistic Television: In this course we will look at television series defined by narrative complexity developed over the course of a season and beyond. We will watch whole seasons of such shows as The Sopranos, Mad Men, The Wire, Six Feet Under, and Slings and Arrows, which bear greater similarity to the novel than to traditional, episodic TV. We will trace the development of the novelistic form of television from the first wave of "quality television" series in the 1990s, in which HBO changed the way people conceived of the artistic possibilities of the medium, through the 2000s, when The Wire and Mad Men fully exploited the new form, and finally into the streaming era, when it has become common but less innovative. We will read media history and theory, and narrative theory to develop an understanding how and why the new form emerged. We will endeavor to understand these shows as expressions of and commentaries on the social and political conditions under which they were produced. We may read a novel or two for purposes formal comparison, and we will watch some episodes of more traditional TV series. Likely theorists include Raymond Williams, Linda Williams, Jason Mittell, Pierre Bourdieu, and Fredric Jameson.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-440 Postcolonial Theory: Diaspora and Transnationalism

Intermittent: 9 units
Arjun Appadurai argues that one of the primary transformations in this period of globalization has been in the capacity for people to imagine themselves or their children will live and work in places other than where they were born. Although the novel has long been considered a national form, contemporary novels frequently represent transnational mobility, both in their plots and as global commodities. A significant body of contemporary fiction focuses on imaginative and physical movement across national borders. This global literature course combines literary and theoretical readings to examine the experiences of transnationalism and diaspora. Theories of transnationalism look at the interconnections that cut across nations. The concept of diaspora, a term first used to reference the movement of a people out of a homeland, has become a way to think about the identities of immigrants, migrant workers, and refugees. Readings for the course will be drawn from a diverse group of writers from around the globe. Literary readings might include works by Caryl Phillips, Jamaica Kincaid, Christina Garcia, Nadeem Aslam and Jhumpa Lahiri; theoretical readings might include works by Salman Rushdie, Paul Gilroy, Gloria Anzaldúa, Arjun Appadurai, Inderpal Grewal and Avtar Brah.

76-442 Black Lives in Pre-1900 Britain

Intermittent: 9 units
This course engages with Black voices writing from, to, about, and against Pre-1900 Britain, from abolitionists to actors to royalty. We explore topics including racial philosophy, the transatlantic slave trade, revolution, abolition, imperialism, and popular culture, from both contemporary and modern sources. Our texts and conversations trace how the lives and experiences of individuals like Ignatius Sancho, Sarah Baartman, Ira Aldridge, and Alemayehu Tewodros presage those of a modern global Black diaspora.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-445 Milton

Intermittent: 9 units
Although censored and reviled by many in his own day, John Milton (1608-1674), author of Paradise Lost among other powerful anti-monarchical writings of the English Revolution, has influenced writers as varied as William Blake, Mary Shelley, Thomas Jefferson, Friedrich Engels, C.S. Lewis, Malcolm X, and Philip Pullman. This course will investigate what has made Milton a writer at once so much imitated and beloved by his admirers and loathed and denigrated by detractors. The bulk of this course will center on a careful, challenging, and chronological reading of Milton's works, primarily Paradise Lost but also his great shorter poems including Lycidas, Paradise Regain'd, and Samson Agonistes, and selections of his voluminous prose (Areopagitica, Of Education, Tenure of Kings and Magistrates, Readie and Easy Way to Establish a Free Commonwealth). Studying Milton's development as a poet, controversialist, and pamphleteer, students will examine Milton's contexts (chiefly, literary, political, and theological) in order gain further insights into the complex relations between Milton's 17th-century world and his major poems and prose. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-446 Revenge Tragedy

Intermittent: 9 units
Attendants to the early modern English theater seem to have had an almost insatiable appetite for revenge tragedy: a lurid, blood-soaked genre distinguished by plots involving insanity, skulls, ghosts, poisonings, stabbings, suicide, and other forms of unnatural death. This course will cover key examples of the genre, putting particular emphasis on the depiction and interrogation of justice, analyses of death, and playful engagement with theatricality. Our central curriculum will include the following plays: Thyestes (Seneca), The Spanish Tragedy (Kyd), Titus Andronicus (Shakespeare), Hamlet (Shakespeare), The Revenger's Tragedy (Middleton), and The Duchess of Malfi (Webster). We will also read a selection of critical essays and related literature from the period.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-108 and 76-106)

76-448 Shakespeare on Film

Intermittent: 9 units
The dramatic works of William Shakespeare have inspired an extraordinarily rich and varied cinematic legacy that began in the era of silent films and now boasts masterpieces by directors such as Akira Kurosawa, Roman Polanski, Peter Greenaway, and Orson Welles, not to mention history-making performances by icons including Marlon Brando, Elizabeth Taylor, Laurence Olivier, Al Pacino, Leonardo DiCaprio, and Ian McKellen (among many others). This course will consider a selection of key Shakespeare films alongside critical readings centered on questions of adaptation and performance. As we watch and read together, we will work toward a broader understanding of what Shakespearean drama means in a 21st century context, and how film has helped to shape the author's massive cultural impact.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-450 Law, Culture, and the Humanities

Intermittent: 9 units
"I'm not a lawyer, but..." How many times have you heard this disclaimer, closely followed by a lay analysis of law? This course, an introduction to the cultural study of law for graduate students and advanced undergraduate students, can be seen as an introduction to what goes into the making of such a statement. Where do we get our ideas about law? What do we mean when we say "law"? What counts as law? How does culture influence law, and law, culture? And to what degree should historical context condition any answers we might be tempted to give? Students in the course will study works in a range of genres (novels, plays, poems, judicial opinions, pamphlets) and develop methods for investigating ways that law and culture have been made by one another from the 16th-century to the present. Readings will include influential theoretical accounts of law (Aristotle, Hobbes, Cover, Habermas, Bordieu, MacKinnon, Alexander), canonical texts in Law and Literature (Shakespeare's Measure for Measure, Melville's Billy Budd, Kafka's The Trial) and some "weird fiction" by the novelist/legal theorist China Mi and #233;ville. As a counterpoint to the fiercely anti-historical "law and economics" movement, however, the course will put special emphasis on rooting intersections of law and culture in rich historical context, considering both local and international legal contexts (sometimes in fairly technical detail) alongside so-called "ephemera" of culture. Students will tackle the especially fruitful "case" of Renaissance Britain before developing final research projects, whether on the Renaissance or another period of their choosing.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-452 Generations and Culture

Intermittent: 9 units
We frequently hear about generations and #8212;the Millennials and their multitasking, Gen X and their minivans, and the Baby Boomers and their self-satisfaction and #8212;but generations have usually been ignored in cultural studies. Yet generations have significant impact on cultural tastes, consumer choices, and political views, as a good deal of research shows, and identity, alongside other factors such as race, class, gender, sexuality, ethnicity, and abledness. This course will study the theory of generations, as well as novels and films that tell us about generations. Please note: first-year students are prohibited from registering for this course. Sophomore students require instructor permission.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-453 Literature of Empire

Fall: 9 units
Nineteenth and early twentieth-century British literature was shaped by events taking place outside as well as inside of national borders. Even in the eighteenth and nineteenth centuries, with international trade and slavery supporting the manor house and plantations abroad providing the cotton for British looms, the "England" of English literature spanned the globe. By the first half of the twentieth century, this empire had begun to collapse in upon itself, a process witnessed by writers inside Britain and its colonies. This course will investigate British literature within the international context of global imperialism. A section on gothic stories takes us into the realm of popular culture with Mary Shelley's Frankenstein and Arthur Conan Doyle's short stories. We take to the seas with Joseph Conrad's Lord Jim, before we consider W. Somerset Maugham's exploration of sexuality in the tropics in The Painted Veil. Finally, we return to England to outline the links between colonial empire and international war rendered in Virginia Woolf's Mrs. Dalloway. These literary works will be read alongside some of the most important works of postcolonial theory. While course readings focus on 19th and early 20th century, student's will undertake a research project over the semester in their own period of interest in British literature in connection with empire studies.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-107) or (76-106 and 76-108)

76-454 Rise of the Blockbuster

Intermittent: 9 units
The term "blockbuster" has been a part of the American film industry for over sixty years, but, like "pornography," it's extremely difficult to define from a critical standpoint. For most of the viewing public the "we know it when we see it" definition seems to suffice. In an academic sense, however, such vagueness is problematic. This course will explore the idea of the "blockbuster" over time and across cultural boundaries. What is the origin of the concept? What is the structural impact of the "blockbuster" on the film industry? How does the meaning of the term change from genre to genre? Is it a genre in and of itself? How does a "blockbuster" reinforce our cultural conceptions? How might the concept change in the future? What does all of this tell us about ourselves? This course will draw examples from across the history of film in order to develop a holistic understanding of what the term might encompass from a variety of perspectives. By thoroughly discussing a wide selection of texts we will be able to better understand the ways in which the "blockbuster" has influenced the film industry, how the concept has both manifested itself and changed over time, and how it has shaped our cultural perspectives. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.
Prerequisite: 76-101

76-456 Independent Study in Film & Media Studies

All Semesters
TBA
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-457 Rhetorical Invention

Fall: 9 units
Rhetorical invention refers to the discursive process of inquiry, discovery, and problem solving, or how we decide what to say, what arguments to advance, and what means of persuasion to use in any situation. Although invention is centrally important to rhetoricwithout which it becomes a superficial and marginalized study of clarity, style, and arrangementfrom the Scientific Revolution and Enlightenment through the mid-twentieth century invention all but disappeared as a topic of rhetorical study under the pressure of the view that invention should be exclusively governed by deductive logic and the scientific method rather than rhetorical considerations such as audience or the figurality of language. This repudiation of rhetorical invention fundamentally shaped modern thought and continues to influence the ways we think and communicate today. In this course, we begin by examining the status of rhetorical invention in the development of modern thought before focusing on various scholarly efforts to revive a rhetorical understanding of invention from the mid-twentieth century forward, surveying a variety of contemporary theories of rhetorical invention including those promoted by postmodern, posthuman, and digital rhetorics. The course is designed to explore the central importance of invention to contemporary rhetorical theory through a pairing of historical and contemporary readings.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-458 Sociology of Literature & Culture

Intermittent: 9 units
This course introduces you to the sociology of literary and cultural media, emphasizing how texts arise within "the field of cultural production" and its dynamics. We will first read in the classical social theory of Max Weber, Emile Durkheim, and Karl Marx, then move to late 20th and early 21st century sociological thinking about literature by Raymond Williams, Pierre Bourdieu, Bruno Latour, Sara Ahmed and others. Key topics will include the problem of social conditioning and "habitus"; the structure of the literary and media fields; the question of "affect" and emotiona topic not usually considered sociologicalin the writing of Ahmed, Williams, and others; the politics of social networks in Latour and other network theorists who have been aiming to redefine what the "social" means. Literary writers to be read alongside these theorists will include William Blake, the Shelleys, Herman Melville, William Morris, Bertolt Brecht, and Toni Morrison. The last two weeks of the course will be devoted to students' presentation of their research. Two papers and several in-class presentations will be required. This course is for juniors and seniors only.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-460 Beginning Fiction Workshop

Fall and Spring: 9 units
In this writing-intensive workshop students will be laser-focused on producing and polishing their own fiction. We'll complement our workshops with readings from masters of short fiction and novels, with an eye on sharpening our own facility with dialogue, structure, and voice. Each student must be prepared to constructively critique and deconstruct her/his peers' work, as well as actively contribute to class discussions about the elements of craft that undergird successful works of fiction. Each student will be expected to produce a portfolio of original writing (short exercises originating from thematic prompts and a substantial story) by the end of the semester.
Prerequisite: 76-260 Min. grade B

76-461 Refugee Stories: Literature, Art and Film

Intermittent: 9 units
Contemporary literary, film and other visual culture have reimagined the experiences of transnational migration and asylum claims. These global works focus on recent and ongoing wars, state regulations, borders, detainment, and transnational labor. In this discussion-based, interdisciplinary course, students will study Anglophone and some translated global literature, documentary and feature film and photojournalism, art installations, and digital activist projects. We will ground our analysis using theoretical insight from Critical Refugee Studies, Postcolonial and Decolonial Studies. We will encounter a wide range of forms, aesthetics and themes that represent these experiences, including unexpected elements like humor, romance and horror. Possible readings might include Dina Nayeri, Viet Thanh Nguyen, Thi Bui, Isabel Allende, Valerie Luiselli, Mohsin Hamid, and Shailja Patel; art by Ai Weiwei, Marc Quinn, Christoph B and #252;chel, Banksy, Mona Hatoum and Reza (Deghati); and films/television by Remi Weekes, Sally El Hosaini, Jonas Poher Rasmussen, Mohammed (Mo) Amer.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-462 Advanced Fiction Workshop

Fall and Spring: 9 units
This course will give you experience reading and writing in two genres: fiction and creative nonfiction. The course is discussion based, and several classes per month will be devoted to generative, in-class writing exercises, which students will then work on as drafts to revise. Readings will include novels, stories, essays, and short journalistic pieces. Attendance and participation is mandatory. If you're interested in delving more deeply into the craft and art of these prose genres, and willing to put the time in to develop your own writing, this is a good class for you. I stress that a classroom is a community, and emphasis will be on establishing real connection between students. We will see how writing can help create and build on these connections between people, and serve as a tool for healing during a particularly rough time in our culture.
Prerequisites: (76-260 Min. grade B and 76-460 Min. grade B) or (76-261 Min. grade B and 76-460 Min. grade B)

76-464 Creative Nonfiction Workshop

Intermittent: 9 units
Narrative Medicine looks at the intersection of writing and healing. How does narrative help heal the mind, and how are the mind and body inextricably linked? The couse will introduce you to several books and essays centered around the theme of wellness and illness and #8212;- and how these modes of being are represented and shaped by culture. You will write your own personal essays on these topics along with a final research paper. A great class for anyone interested in the power of story-telling in our own lives.
Prerequisites: 76-265 Min. grade B or 76-365 Min. grade B or 76-460 Min. grade B or 76-262 Min. grade B or 76-260 Min. grade B or 76-261 Min. grade B

76-465 Advanced Poetry Workshop

Fall and Spring: 9 units
In this workshop, we'll investigate what's possible in poetry, as participants examine their relationship to the poetic practice both as readers and as writers. Through writing exercises, discussion, and readings, we will explore the diverse landscape of contemporary poetry, and experiment with form and technique. As we study different methods of making a poem, and different notions of what makes a poem, and what makes a poem great, participants will work to discover imaginative ways of approaching the line and the page.
Prerequisite: 76-365

76-467 Crime Fiction and Film

Intermittent: 9 units
This course will be concerned with hardboiled crime fiction in print and on screen. The hardboiled emerges in Ernest Hemingway a distinctive literary style, and about same becomes a formula for pulp crime fiction. The language and attitude of the hardboiled became associated with urban gangsters in films such as The Public Enemy. Newspaper crime coverage beginning in the 1920s becomes increasingly frank in both its language and photographic coverage of crime. These various elements will be the material for a new kind of literature represented Dashiell Hammett, James M. Cain, and especially Raymond Chandler, and for a cycle of films that owe much to their work, film noir. Chandler was responsible for invention of one of most enduring types in American fiction, the hardboiled detective. The course will focus on Chandler and the crime stories after him that make various uses of that type and the formula that has become associated with it. Throughout the course we will consider the social and political contexts in which these cultural forms developed, and what cultural work the hard-boiled performed. We will be especially interested such questions as the function of the misogyny typical of much of it, the different representations of race by white and black artists, the representation of police, whether the hardboiled is best understood as having a working-class affiliation, and the degree to which its various manifestations might be called realist. NOTE: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-468 Space and Mobilities

Intermittent: 9 units
This course will investigate space and movement as social constructions. Space is something dynamically created that may be interpreted for the ways it creates meaning, while movement reproduces and constitutes power and institutions. This interdisciplinary course considers theories of space and movement as a field of study and in reference to literary and film texts. The course might include discussions of migrants and state borders, cultural constructions of transport, the poetics of space, and the dynamic mapping of the city through movement and sound. Readings might include Henri Lefebvre, Doreen Massey, Edward Soja, Gaston Bachelard, Wendy Brown, John Urry, Tim Cresswell, Marian Aguiar; literary texts might include Brian Friels Translations, Christina Garcia's Dreaming in Cuban, W.G. Seabald's Austerlitz and Teju Cole's Open City. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission. Students across disciplines are encouraged and may work on a final project related to their primary field.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

76-469 Screenwriting Workshop

Spring: 9 units
This semester will begin with a review of the fundamentals of screenwriting, including character development, scene construction, dialogue, and story structure. Student work will include exercises that encourage writers to take creative risks with genre, tone, character, and structure, one collaborative project, and two short scripts. We will also view mainstream, personal, and experimental narrative films in both American and international cinema.
Prerequisite: 76-269 Min. grade B

76-473 Rhetoric & the Construction of Race

Intermittent: 9 units
In their seminal book on race, Michael Omi and Howard Winant write that race is "socially constructed and historically fluid." This course takes their assertion seriously by examining the role of communicative practices in constructing race, from discourses around the NFL national anthem protests to dominant discussions around transnational and transracial adoption. We'll look for common themes in the discourse around certain events and practices, asking why certain ideas or tropes are used and repeated, and what historical, social, cultural, and political associations inform these tropes that help them to perpetuate racial stereotypes in popular culture without overtly claiming racism. Students will practice thinking critically about everyday cultural narratives, and produce a final paper identifying the work one such set of narratives does to shape reality and create, reinforce, or perpetuate the construction of racial meanings.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

76-474 Software Documentation

Spring: 9 units
This course teaches theory, techniques, and best practices for creating software documentation. We will learn to plan, architect, write, and publish audience-appropriate user assistance, while applying concepts and approaches like minimalism, topic-oriented authoring, single-source publishing, content reuse, and metadata. Students will complete homework assignments and larger projects to reinforce principles and provide experience in all phases of the software documentation lifecycle. Readings and class discussion will bridge theory and practice. This course is for juniors and seniors only.
Prerequisites: 76-270 or 76-271

76-475 Law, Performance, and Identity

Intermittent: 9 units
Although rhetoric and law have long been closely associated, the modern professionalization of law has often promoted the idea that legal discourse is not rhetorical but a rigorously defined technical discourse that can be applied free of social, cultural, or political considerations. This view of legal discourse is disputed by critics who point out the figurative aspects of legal language, the relevance of character, emotion, and narrative in legal communication, and the ways in which law protects social structures of power such as race, class, and gender privilege. The course broadly examines the fraught relationship between rhetoric and law by considering the ways in which a variety of legal discourses serve to construct and reinforce identities, with a particular focus on the ways in which legal systems are portrayed to reflect the ideals of democracy to suit particular foreign relations goals. We begin by studying the ways in which Cold War foreign policy goals influenced desegregation and civil rights discourse in the United States, then we turn to the ways in which the prosecutions of deposed authoritarian rulers in various regions of the globe have been orchestrated to persuade global audiences that emerging democracies observe the "rule of law" for purposes of garnering international support. Alongside primary sources of legal discourse, we will study a selection of interdisciplinary scholarship about the relationship between rhetoric and law. Students write a two-stage research paper on a topic of their choosing regarding the relationship between legal discourse and the construction of identity. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-476 Rhetoric of Science

Fall: 9 units
This course explores questions about scientific argument and communication that are of interest to students in the sciences, rhetoric, and professional/technical writing. These include questions like: How are scientific arguments structured? How is scientific information and argument transformed when it moves from research papers for specialist audiences to publications for non-specialists? How does the social, historical, and cultural context of science shape the way it is communicated and/or argued? What contributions do visuals make to scientific argument and communication? To investigate these questions, we will be examining a wide variety of real-world communications in and about science as well as texts in rhetoric, history, and philosophy of science.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-479 Model Minorities? Race, Rhetoric, & Identity in Asian America

Intermittent: 9 units
"Asian American" is a self-conscious political identity developed by pan-Asian ethnic groups in solidarity with one another in 1968. What does it mean now, 55 years later, to be Asian American? How do Asian Americans fit into the differentially racialized landscape of the U.S., and how, in turn, are Asian American identities and experiences shaped and expressed in culture? How does the political and activist history of Asian America inform social movements today? And how do rhetorical scholars engage Asian American communities, identifying both varied processes of racialization, and patterns of counterdiscourses in which Asian Americans speak against the mainstream images that have circumscribed their subjectivities? This course brings together Asian American studies and Asian American rhetoric with a focus on the study of culture, examining the currents of global and domestic power that have shaped Asian American experience, the movements and communities that have acted in solidarity among and against those forces, and the communicative practices that both shape and are shaped by Asian Americans. By the end of the course, students will be well versed in significant topics and theories in Asian American studies and Asian American rhetoric, and will produce a final paper analyzing a topic, issue, policy, movement, or historical/cultural artifact that speaks to, or illustrates a new nuance about, Asian America. This course is for juniors and seniors.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-481 Introduction to Multimedia Design

Fall: 12 units
This class meets the increasing demand for professional/technical writers who understand multimedia and its communicative possibilities. It provides students with the opportunity to create both an explainer video and a more persuasive animation merging text, spoken voice, music, images, and video clips. Students will learn the basic concepts and vocabulary of motion graphics, practical issues surrounding designs that change over time, and digital storytelling through hands-on projects. Inspiration is drawn from popular Vox and Ted Ed explainer videos that have come to represent the genre. Students explore writing and recording their own narration and how to best utilize elements of time, motion, and sound to enhance their visual communication skills. Adobe After Effects will be taught to complete assignments and explore multimedia possibilities. Some Adobe Photoshop, Illustrator, and Audition will also be taught to support specific tasks. Basic experience with Photoshop or Illustrator prior to taking this class is helpful, but not required. In-class discussions and critiques are essential components of the course.
Prerequisites: (76-270 or 76-271) and (51-261 or 51-262 or 76-391)

76-482 Rise of the Art Film

Intermittent: 9 units
The years between 1945 and 1970 saw an explosion of filmmaking talent around the world. Directors such as Vittorio De Sica, Jean-Luc Godard, Agnes Varda, Akira Kurosawa, Ingmar Bergman and Satyajit Ray completely changed the way narratives looked on screen. Just as important, however, was the fact that American audiences used to the standards and storytelling strategies of the Hollywood studio system were suddenly presented with a variety of international cinemas which collectively came to be known as "art films." This class will examine a broad cross section of such films while also scrutinizing the impact of the "art film" on Hollywood narrative strategies, domestic distribution networks, film criticism and American culture.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-483 Research Methods in Technical & Professional Communication

Fall: 9 units
This course provides you with practical, hands-on experience with designing, collecting, and analyzing research in Technical and Professional Communication. These same research methods are also applicable to Writing Studies and classroom research. We will go into depth on three main methods in this class: interviews, surveys, and think-aloud protocols. In addition, we will touch on focus groups, eye-tracking analysis, and collaborative analysis techniques. More specifically, in this class you will learn how to design well-worded questions that produce reliable information; critically reflect on and improve your interview technique; explore software designed to aid in open-ended analysis of qualitative data; design an A/B (or control/experimental) study; write a data-driven research report, and experiment with a range of data collection techniques. Students taking the course for 12-units will have additional readings that look at how these research methods have been applied in Technical and Professional Communication and Writing Studies.
Prerequisites: 76-270 or 76-271

76-484 Discourse Analysis

Fall: 9 units
Discourse is a focus of study in most of the humanities and social sciences, and discourse analysis is practiced in one way or another by anthropologists, communications scholars, linguists, literary critics, and sociologists, as well as rhetoricians. Discourse analysts set out to answer a variety of questions about language, about writers and speakers, and about sociocultural processes that surround and give rise to discourse, but all approach their tasks by paying close and systematic attention to particular texts and their contexts. We are all familiar with the informal discourse analysis involved in paraphrasing the meanings of written texts and conversations, a skill we learn in writing and literature classes and in daily life. Here we ask and answer other questions about why people use language as they do, learning to move from a stretch of speech or writing or signing outward to the linguistic, cognitive, historical, social, psychological, and rhetorical reasons for its form and its function. As we look at resources for text-building we read analyses by others and practice analyses of our own, using as data texts suggested by the class as well the instructor. In the process, we discuss methodological issues involved in collecting texts and systematically describing their contexts (ethnographic participant-observation and other forms of naturalistic inquiry; transcription and "entextualization;" legal and ethical issues connected with collecting and using other people's voices) as well as methodological issues that arise in the process of interpreting texts (analytical heuristics; reflexivity; standards of evidence). The major text will be Johnstone, Barbara. 2008. An Introduction to Discourse Analysis. 2nd ed. (Malden, MA: Blackwell Publishers). Other reading will be made available as .pdf files.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-487 Information Architecture & Content Strategy

Fall: 9 units
In the digital age, the vast amount of information available online can be overwhelming, and even individual websites often struggle to present their content in a user-friendly manner. In this course, students will immerse themselves in a semester-long real-world project with practical exercises designed to address this challenge. This course equips students with the skills necessary to develop user-centered information architecture and content strategy/design, enabling them to create user-friendly websites that align with user expectations and industry best practices. Throughout the course, students will adopt a user-centered approach, utilizing essential usability methods to gain insights into the information needs, behaviors, and preferences of users. They will develop the ability to identify and rectify usability issues on websites. Additionally, students will delve into the principles of online information design, encompassing topics such as information architecture, navigation, and effective labeling. In the required lab section of the course, students will gain hands-on experience with core web technologies, including HTML and CSS, to shape and style web content. They will also gain an understanding of JavaScript and APIs, which play a pivotal role in integrating data and services into websites.
Prerequisites: (76-102 or 76-101 or 76-272 or 76-270 or 76-271) and (51-261 or 51-262 or 76-382 or 76-391)

76-488 Information Architecture & Content Strategy Lab

Spring: 3 units
Lab exercises for this course include the following: basic HTML, images, tables, animation, image maps, interactive forms, Web interfaces to databases, and basic Javascripting. All students must do the lab exercises. The exercises are designed so that those students who already know particular topics (e.g., basic HTML) do not need to attend the lab session. Students who would like guided practice in doing the lab exercises must attend the lab session. Lab sessions take place in a computer cluster.
Prerequisites: (76-271 or 76-379 or 76-270) and (76-382 or 76-383 or 76-391)

76-490 Digital Rhetorics

Intermittent: 9 units
As most of the communication now takes place using digital technologies (such as Generative-AI, blockchain, AR and VR, and the Internet of Things), the nature of public speech has been fundamentally transformed in these environments. This course explores the connection between rhetoric, socio-political systems and digital media. In today's world, it is difficult to separate digital from human. Students in this class will examine a variety of digital media as they intersect with humans as well as with theories of rhetoric. Students will also have the opportunity to explore digital technology by actively participating in digital spaces and creating digital artifacts. The course provides in depth coverage of rhetoric as an historically rooted but evolving humanistic perspective covering argumentation and figuration, performance and text, and delineating its connections to logic, aesthetics, politics, and ethics.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-491 Rhetorical Analysis

Intermittent: 9 units
Students in this course will learn various approaches to analyzing discourse artifacts from a rhetorical point of view. Early in the course, students will identify an artifact or artifacts they wish to analyze. From there, students will be encouraged to explore their own methods of analysis based on two required books for the course and reviews of literature. For the midterm, students will create an annotated bibliography of five specimens of criticism taken from a single journal. For the final project student will first present and then hand in a polished 15 page piece of criticism based on one or some combination of methods. The presentation and final paper count 50% of the grade, with the mid-term, class attendance, participation, and homework making up the final 25%.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-492 Rhetoric of Public Policy

Intermittent: 9 units
This course explores a rhetorical approach to public policy which focuses on the interconnected role that data, values, beliefs, and argument play in the policy process. From this perspective we will examine the important public debate over the pros and cons of various forms of energy production including nuclear, natural gas, and solar. In these investigations, we will explore questions like "How do policy makers use rhetoric to shape public perspectives on energy production?" "How can rhetorical approaches to argument function as tools for policy analysis and development?" And "What role does technological expertise play in public debate?" To pursue these questions, we will be reading works in rhetorical theory and public policy and applying the concepts and methods in those works to exploring primary artifacts of public argument like records of public hearings, social media memes, handbooks designed by activists, and stories about energy production in the popular media.
Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

76-494 Healthcare Communications

Fall: 9 units
Healthcare communications is designed for students with an interest in how medical and health care information is constructed and transferred between medical experts, health care providers, educators, researchers, patients and family members who are often not experts but need a thorough understanding of the information to make important health decisions. Throughout the course, we will explore the interactions of current theory and practice in medical communication and the role of writing in the transfer and adoption of new therapies and promising medical research. We will also study how the web and social media alter the way information is constructed, distributed, and consumed. We will examine the ways medical issues can be presented in communication genres (including entertainment genres) and discuss how communication skills and perceptions about audience can influence clinical research and patient care. Additionally, we will explore clinical trials, grant writing, and press releases, and will feature guest speakers from these fields will discuss their experiences.
Prerequisites: 76-271 or 76-395 or 76-270

76-495 Other People's Words: The History, Theory, and Practice of Interviews

Intermittent: 9 units
In literary studies, we usually draw our research from books and articles, or sometimes from documents in archives. But one other way to find out information is from interviews. Historians, anthropologists, and journalists use interviews, albeit in different ways. How might we apply their methods to literary study? This course will look at different modes of interviewing. You will also conduct various kinds of interviews yourselves. Thus the course will be a mix between a criticism course and a workshop. Through the semester you will be responsible for conducting and editing one long-form interview with a person about art, literature, or another field. In addition, you will develop a project conducting multiple interviews on a topic. Lastly, you will build a portrait or report drawn from one of those projects.
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-496 Research Methods in Rhetoric & Writing Studies

Intermittent: 9 units
NOTE: This course is only available for seniors with special permission. This course is a survey introduction to historical, empirical, text-based, and qualitative methods of inquiry used in the fields of rhetorical and writing studies. We will read broadly to understand the philosophical questions, research traditions, practical applications, and innovative directions that shape the field, exposing students to a range of methods and methodologies. Studies of rhetoric, writing, and literacy have evolved tremendously, and we will examine approaches for how to trace, analyze, and critique the use of meaning making in a variety of cultural, political, workplace, technological, and pedagogical contexts. By the end of the course, students will develop a sense of how to put together an effective research project on their own and design and articulate the research methods and methodologies appropriate to that study. Throughout, we will ask a fundamental question: How do rhetoric, writing, and literacy work and for what consequences?
Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-700 Professional Seminar

Fall: 3 units
This weekly, 3-unit seminar is designed to give professional and technical writing majors an overview of possible career and internship options and ways to pursue their professional interests. Each session will feature guest presenters who are professionals working in diverse communications-related fields such as web design, journalism, public relations, corporate and media relations, technical writing, medical communications, and working for non-profits. The visiting professionals talk about their own and related careers, show samples of their work, and answer student questions. The course is required for first-year MAPW students and is open to all English undergraduates, who are urged to participate in their sophomore or junior years to explore options for internships and careers.

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-702 Communication Support Tutoring Practicum

Fall
The Communication Support Practicum is designed to introduce students to communication scholarship and pedagogy as well as the methods and theories that inform them for the purpose of communication support and tutoring in CMU's Student Academic Success Center. Students will explore communication (written, oral, and visual) in multiple disciplines and genres with a focus on gaining knowledge and skills to respond to communicators and their texts. Lectures, discussion, and assignments will offer a chance to think critically about tutoring practices and the ideologies and values on which they are based as well as ways to challenge the bias inherent in them. There will be many occasions to reflect on and evaluate tutoring skills, observe others in tutoring situations, and practice a variety of methods that consider the different needs of communicators. Students will gain awareness of how various spaces, identities, technologies, and abilities inform textual production as well as how to create a meaningful response to meet the diverse needs.

Course Website: https://www.cmu.edu/gcc/faqs/index.html (https://www.cmu.edu/gcc/faqs/)

76-708 Literary Journal Publishing

All Semesters
In this course, students will learn about the landscape of and publication process for literary journals in the United States. We will read a variety of literary journals in print and online, will host guest speakers, and will do a variety of hands-on activities related to editing and publishing. Students will gain experience by working on The Oakland Review, an international literary journal run out of CMU, in capacities as varied as editorial, design and production, or promotion. If you are interested in registering for this course, please go to the Course URL and fill out the questionnaire. Thank you.

Course Website: https://form.jotform.com/CMUEnglish/literary-journal-publishing-course (https://form.jotform.com/CMUEnglish/literary-journal-publishing-course/)

76-719 Environmental Rhetoric

Fall
Should you take a hike or seize the mic? Environmental rhetoric combines commitment with contention We start by exploring its multiple discourses, from Muir's vision of conservation, to Leopold's introduction of ecology, to Carson's call for public action, to contemporary scientific research and competing public discussions. To uncover their hidden logic, we study rhetorical strategies first, for analyzing arguments (over issues such as wolves, clean water, or sustainable design), and then for communicating risk (in the face of climate change, fracking, as well as wind power). In response, this course will prepare you to act as a research-based rhetorical consultant for a group of your choice, analyzing the issues and arguments it faces, in order to propose a rhetorically effective response, supported by your own imaginative prototype of a brochure, web page, press release.

Course Website: http://www.cmu.edu/dietrich/english/index.html (http://www.cmu.edu/dietrich/english/)

76-720 Leadership & Organizational Communication

Intermittent
Please note: In order to register for this course, students must have had an internship with an organization prior to registration. Even as most organizations continue to change, one constant is the importance of effective communication. Upward, downward, and lateral communications are the lifeblood of organizations. If you are in a leadership position, communication become your key tool for managing teams, improving performance, and creating change. In any position, you can spearhead progress by designing effective documents and improving existing communication practices. Proficiency in written and oral communications tends to be recognized and rewarded in organizations. Combined with the ability to leverage formal organizational structures and social networks, it helps one excel, and thrive, in organizations. This course is designed as an overview to the field of organizational communication with an emphasis on leadership roles and behaviors. The content will blend the conceptual with the practical. It will focus on problems that are likely to arise in the workplace and ways to solve them through communication. The students will build a portfolio of "solutions" that will demonstrate their evolving skills of applying rhetoric in organizational contexts. Specific topics will include the attributes of great communicators (including leaders and managers as communicators), the challenges of communicating in organizations as we play particular roles (e.g., individual contributor, manager or team member), ways to build credibility and enhance internal resumes, and techniques to master communication requirements related to performance management processes, conflict situations, and changing organizational culture and design. We will also explore a myriad of organizational issues such as communicating across generations and cultures, communicating externally, and communicating through technology.

76-727 Equity & Communication: Strategies for Institutional Change

Spring
Communication is always embedded in power relationships with unstated social rules that govern who is able to say what when. But communication also offers us a tool for rewriting oppressive social scripts. In this class, we will look both at inequities built into our communication and strategies for overturning these inequities. The focus will be on practical actions that you can take to improve your school, workplace, or extracurricular groups. Our readings will come from diverse sources and fields, including sociolinguistics, psychology, education, organizational communication, and writing studies. While our readings might occasionally depress (or enrage) you, the overall focus of the course will be optimistic, challenging you to imagine solutions to the problems we discuss.

76-729 Performing Race in Early Modernity

Intermittent
The earliest known use of the term "white" in reference to Europeans occurs in The Triumphs of Truth, a 1613 play by Shakespeare's contemporary, Thomas Middleton. In addition to suggesting an important connection between race and drama in 17th-century England, this simple historical note raises a range of questions that have a direct bearing on some of the most pressing issues of the 21st century: Where do ideas about race come from? By what processes do the distinctions of racial concepts emerge, evolve, calcify, and mutate? How does the conceptualization of race relate to media? How do racial representations bolster and conduct political power? In this course, we will broach these questions by taking a close look at the race-making function of drama in early modernity, a period when race was an inchoate, incipient concept, caught up with the emergence of colonialism, capitalism, and increasing interconnection between peoples, cultures, and worlds. As we think, read, and converse together, we will endeavor to come to terms with the problems and paradoxes of racial representation in the early modern theater, a forum that offered access to innovative, daring thinking about human equality and ethical responsibility, but was also a site for the perpetuation of hateful stereotypes and exploitative theories of white supremacy. In a wide-ranging survey of drama, historical documents, and contemporary criticism, we will work toward an understanding of how race-based concepts operated in the theater, and how the drama early of modernity continues to influence thinking about race in our own time. This course meets the Dietrich College Reflecting Gen Ed requirement.

76-731 Dissenters and Believers: Romantics, Revolution, and Religions

Intermittent
This course examines the relation of Romantic writing to religion in the age of revolutions. We will read a number of Romantic-age writersWilliam Blake, S. T. Coleridge, William Wordsworth, Edmund Burke, Monk Lewis, Percy Shelley and #8212;in relation to the most "orthodox" religious modes (Anglican, Catholic, Lutheran, and Evangelical) and the most "heterodox"Enthusiasm, Rational Dissent, Unitarianism, Deism, Pantheism, or atheism. We will also distinguish between "religions" (as formally institutionalized) and "religiosity"defining religiosity as more diffused or displaced feelings, ideas and practices that are often not clearly marked as religious or related to any one institutional religion. Two papers are required.

76-749 Climate Fictions

All Semesters
During the last 20 or so years, a new kind of fiction has emerged responding to scientific models of climate change. Climate fiction, or "cli-fi," most often imagines a future in which nothing has been done or done soon enough to limit global warming. Much of this literature fits into the broad genre of science fiction, but some of it uses other fictional modes, including realism and postmodernism. This course will look at a variety of fictional approaches to climate change, including a few in visual media. We will consider why fiction is a necessary component of our understanding climate changecomputer models are fictions of a sortbut also whether and how fictional narratives such as novels and films can help motivate action. We may also read some earlier narratives of environmental catastrophe, and some nonfictional discussions of climate change. Likely authors include Amitav Ghosh, Margaret Atwood, Barbara Kingsolver, Kim Stanley Robinson, and Richard Powers.

76-750 Critical Theories about Literature

Fall
This course studies the long-debated problem of how readers or spectators respond to texts (in print, performances, film, or painting) from ancient rhetoric and tragedy to contemporary mass culture.We will read in a range of critical theories, from thinkers like Aristotle, Plato, and Longinus to recent theorists in poststructuralism, gender studies, Marxism, and affect theory. How have such critics and theorists thought about the nature of the text and of representation and #8212;or the relation of authorship to reading, ideas, and affects? What techniques of analyzing literary texts have such theories stimulated? Two papers and vigorous in-class discussion will be required.

Course Website: http://www.cmu.edu/dietrich/english/index.html (http://www.cmu.edu/dietrich/english/)

76-754 Watchdog Journalism

Intermittent
The practice of journalism involves covering the news of the day. Investigative journalism uncovers it, digging through public records and data to expose corruption or correct social injustices. The process takes patience and persistence, as well as familiarity with right-to-know laws, to find that gold nugget of information that exposes secrets or becomes the missing piece to a larger puzzle. In this course, students will learn investigative techniques that make the powerful accountable, using government documents, financial filings and databases to spot undetected crime patterns, an unfair housing policy or perhaps questionable spending by a non-profit charity. Investigative journalism has a storied history of exposing wrongdoing and today many of the tools historically used to tell those stories are available to everyone. This course will help budding journalists, researchers and anyone else interested in addressing societal problems find those tools and learn how to use them. This course meets the Dietrich College Deciding Gen Ed requirement.

76-755 Leadership, Dialogue, and Change

Fall
This course offers an alternative to the "great man" theory of leadership and #8212;in which success is built on charisma, power, status, or institutional authority. The contemporary model of "adaptive leadership," however, depends on an ability to draw a divided community into a dialogue that re-frames the problem and may even call on us to re-interpret our values. We will see this in action, comparing the methods of Martin Luther King to the radical community organizing of Saul Alinsky, and in the influential of African-American cultural critiques of Cornel West and bell hooks, and in the work of students calling for change on campuses. All this work poses a question: how does dialogue work in the rhetoric of making a difference? So in the second half, we put theory into practice, organizing a CMU Community Think Tank on a campus issue, in this case on student empowerment will learn strategies for analyzing a problem, framing, issues, giving rhetorical presence to those problems and creating counterpublics that put new ideas into circulation. The class collects data across diverse, often competing perspectives, to create a Briefing Book, that will guide your live Round Table problem-solving dialogues, and then document, write and publish your Findings www.cmu.edu/thinktank. Aa a portfolio project it will demonstrate your ability to support problem-solving dialogues across difference in a community or organization.

76-758 Rhetoric & Storytelling

Spring
What are stories and why do we tell them? What purpose do they serve? What makes a story true? What effect do stories have on those who hear them? In this course, we will ask how narratives work rhetorically to shape how we perceive and encounter events, movements, places, and experiences. Students can expect to read and discuss narrative theories and practice employing these theories to analyze story artifacts, such as written collections, political speeches, newspaper articles, curated experiences, and oral histories. We will begin the semester by exploring and analyzing the many stories surrounding September 11 but will also consider the stories that infuse recent or local subjects of interest. Students will investigate the effect these and other narratives have on contemporary contexts. Any student who is interested in developing a critical awareness of the rhetorical power of storytelling and enhancing their analytical toolkit will benefit from this course. Most class sessions will involve guided student discussions of theoretical texts as well as collaborative opportunities to analyze story artifacts. Weekly assignments will include short analyses and reflection activities. The course will culminate in a final project where students will select and analyze a collection of stories within a cultural, social, and/or historical context.

76-762 Introduction to Translation

Fall: 9 units
In "Introduction to Translation," we will survey a number of different translation theories in order to understand the various approaches that are at our disposal when translating a text. In addition, we will briefly explore several fields of translation studies, such as health care, business or literature, that require specialized terminology and expertise in the subject. All theory taught in class will be accompanied by hands-on translation projects that will give students the opportunity to try out their knowledge first-hand and evaluate the usefulness of different approaches on a personal basis.

76-763 Translation as Profession I

All Semesters: 3 units
In "Translation as a Profession," we will learn from professionals in the field of translation. Every class will feature a guest speaker from the Pittsburgh area and beyond who will present his or her own educational background, experience in the field and current relation to the translation industry. Students will meet a variety of professionals, learn about the field, and establish valuable connections for the future.

76-765 Beginning Poetry Workshop

All Semesters: 9 units
tbd

76-766 Essay Writing Workshop

Fall
In this course we will analyze the different types of narrative structure, narrative suspense, voice, metaphor, and point of view that make for effective non-fiction writing. We will also examine the difference between good writers and good work, the functions of objective distance from and intimate investment in a subject, as well as the philosophical questions spurred by non-fiction writing. What is the non-fiction writer's role, and how does it differ from that of the fiction writer? Where do the two genres overlap? What gives non-fiction writing integrity? What does the term "creative non-fiction" mean? How have the form and aims of non-fiction writing - from memoir to essays to long-form journalism - evolved for better and for worse? We will scrutinize the writing of Eula Bliss, Kate Fagan, Joan Didion, James Baldwin, Jo An Bear, Gary Younge, David Foster Wallace, Umberto Eco, and many others. In addition to critical writing assignments, students will have several opportunities to write their own non-fiction pieces.

Course Website: http://www.cmu.edu/dietrich/english/index.html (http://www.cmu.edu/dietrich/english/)

76-771 Teamwork for Innovators

Fall
Academic teams, campus organizations, workplaces are all dynamic activity systems, organized and driven by institutional habits and rules, by roles, status and power, and by the material and conceptual tools we draw on. Yet as we have all observed, these Rules, Roles and Tools often operate in contradictory ways, even in conflict with one another. Effective team leaders are able to recognize these contradictions and draw a writing group, a project team, a social organization or a workplace into what is called an "expansive transformation." That is, to innovate new ways of working together. In this course, you will learn how to become more effective not only as a team member, but also a project leader, and even group consultant in your college work and workplace. Looking at films, case studies, research, and your own experience, we will learn how to analyze how teams of all sorts are working, to communicate more effectively across different expectations and values, and to collaboratively innovate new ways of working together. Your final project will let you document your ability to be a knowledgeable team leader and effective collaborator.

76-772 News Writing

Fall: 9 units
In this course, we will study and learn the fundamental skills of journalistic writing as well as discuss topics related to how different media outlets cover news. On the writing side, we will start with the basics - the importance of accuracy, clarity and fairness, writing for audience, striving for objectivity, judging newsworthiness, meeting deadlines. The core class work (and most of your grade) will be based on seven writing assignments due approximately every two weeks throughout the semester. Expect to do some writing each class period. We will learn how to write a story lead, how to structure a story and how to write different kinds of news stories, from crime news to features to editorials and commentary. We also will learn how to research a news story, conduct an interview and sort through mountains of information to discern what's important so we can write about it in a clear, concise manner.

Course Website: http://www.cmu.edu/dietrich/english/index.html (http://www.cmu.edu/dietrich/english/)

76-773 Argument

Fall and Spring
This course introduces the fundamentals of argumentation theory and offers guided practice in analyzing and producing arguments. Through analysis, we will learn what an argument is, how to identify one, and what the names and functions of a variety of argument features are. We will also explore the production of argument by pursuing the questions: What are my argumentative goals? How do I build a theory of my audience? What means of persuasion are available for me to achieve my goals? And how should I order the contents of my argument? To answer these questions, we will explore argument in a variety of genres including visuals, op-eds, presidential speeches, and congressional testimonies.

Course Website: http://www.cmu.edu/dietrich/english/index.html (http://www.cmu.edu/dietrich/english/)

76-784 Race, Nation, and the Enemy

Intermittent
Conflicts over racial and national identity continue to dominate headlines in the United States as they often have during the nation's history, from debates regarding the immigration, naturalization, and birthright citizenship of racial minorities to debates regarding racial disparities in access to civil rights. This course explores the discursive practices through which racial and national identities are formed and the frequent conflicts between them, particularly by focusing on the role of enemies, threats to the nation, and sacrifices made on behalf of the nation in American public discourse. Alongside primary sources of public discourse regarding wars, the immigration and citizenship of racial minorities, racial segregation and civil rights, and the criminal prosecutions of dissidents during periods of crisis, we will read secondary sources offering multiple theoretical and disciplinary approaches to the study of racial and national identity formation. Along with regular brief responses to readings, assignments will include a short rhetorical analysis paper and a longer research paper.

76-786 Language and Culture

Fall
This course is an introduction into the scholarship surrounding the nature of language and the question of how language shapes and is shaped by social, cultural and political contexts. We will begin by studying important literature in linguistics and language theory, both to introduce us to how scholars think about language and to give us a shared vocabulary to use for the rest of the semester. We will then move into case studies and theoretical works exploring the intersections of language use, individual and group identities, and the exercise of power, in its many forms. In particular, we will focus on the relationship between language and culture by asking, in what ways does language influence and constitute social change? How is social change reflected by changes in the way we use language? Over the course of the semester, you will work on applying the knowledge and theoretical tools you gain to your own analysis of a linguistic artifact that you choose.

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-787 Writing in the Disciplines

All Semesters
This mini will introduce you to the theory and practice of writing instruction in contexts outside of English studies. We will learn about the distinction between Writing across the Curriculum and Writing in the Disciplines and challenges to providing integrated, high quality writing instruction across the university. We will explore the implications of the wide variety of forms of academic writing for instruction in English classrooms, including high school and first-year writing classrooms. Assessments will include reading responses and a final paper reviewing research on writing in a specific writing context of your choosing. Students enrolled in the course for six units will be expected to do additional readings and give an oral presentation. Please note that in terms of time commitment, a 3-unit mini will require approximately six hours per week (three hours homework and three hours class meetings) and a 6-unit mini will require twelve hours per week.

76-788 Coding for Humanists

Intermittent
This course provides students with the foundational knowledge and skills to develop and/or utilize computer-aided research tools for text analysis. Through a series of hands-on coding exercises, students will explore computation as a means to engage in new questions and expand their thinking about textual artifacts. This course is designed for students with no, or very little, coding experience. So, if you have already taken a programming course, this course is most likely not for you. Students who have taken 15-110 and/or 15-112 may not take this course. For the final project, you will develop a small research project involving a computational analysis of a corpus of texts. You will plan, design, and write a computer program that processes and analyzes a textual corpus of your choice. Students who are taking the course for 9-unit will write a brief project report (3-5 pages) that summarizes your final project. Graduate students in the MA in Rhetoric/PhD programs must register for 12-unit, and will complete a research paper (4,000-5,000 word).

76-789 Rhetorical Grammar

Fall and Spring: 9 units
This is a course in This is a course in fundamental grammatical structures of English and how these structures fit into the writer's toolkit. This means you will learn a lot about English-language grammar in this course en route to understanding a lot about English language writing. This course is designed for MA students in professional writing and undergraduates who want to improve their grammar, their writing, and their depth of understanding of how improvement in grammar impacts improvement in writing.grammatical structures of English and how these structures fit into the writer's toolkit. This means you will learn a lot about English-language grammar in this course en route to understanding a lot about English language writing. This course is designed for MA students in professional writing and undergraduates who want to improve their grammar, their writing, and their depth of understanding of how improvement in grammar impacts improvement in writing.

Course Website: http://www.cmu.edu/dietrich/english/index.html (http://www.cmu.edu/dietrich/english/)

76-790 Style

All Semesters
This course teaches you how to write clearly. Specifically, the principles you learn in this course will help you 1) to clearly represent actions and the characters responsible for them; 2) to make your paragraphs coherent and cohesive; 3) to write sentences that stress important information; 4) to cut unnecessary prose; and 5) to reshape lengthy sentences so as not to perplex your reader.

Course Website: http://www.cmu.edu/dietrich/english/index.html (http://www.cmu.edu/dietrich/english/)

76-791 Document & Information Design

Spring: 9 units
This course provides students who have already learned the foundation of written communication with an opportunity to develop the ability to analyze and create visual-verbal synergy in printed documents. Students will be introduced to the basic concepts and vocabulary, as well as the practical issues of visual communication design through a series of hands-on projects in various rhetorical situations. Assigned readings will complement the projects in exploring document design from historical, theoretical, and technological perspectives. Class discussions and critiquing are an essential part of this course. Adobe InDesign, Photoshop, and Illustrator will be taught in class, and used to create the assigned projects.

Course Website: http://www.cmu.edu/dietrich/english/index.html (http://www.cmu.edu/dietrich/english/)

76-793 Narrative & Argument

Spring
This is a course for non-English majors interested in understanding and practicing writing as an art of design thinking and decision-making. We work through seven writing exercises divided into "experiential" and "informational" clusters and we discuss the underlying design principles that unite and divide these clusters. Experiential writing (think character-based fiction, personal profiles, travel writing, narrative histories) supports reader learning but in an indirect, unsupervised fashion. Students write short papers within each of these clusters to glimpse and grapple with the different compositional (design) challenges. Within experiential writing, students practice making themselves (from the first person) and third parties characters readers can come to know and care about. They practice immersing readers within immediate and historical scenes by creating the feel of extended space or elapsed time. Within information writing, students practice presenting readers with new ideas by following the readers' native curiosity (exposition), guiding readers through manual tasks (instruction), and structuring readers' decision-making (argument) in controversies when there are multiple decision paths. Argument is a capstone of information writing that bids for social and political change. While writing for experience and writing for information are distinct clusters, they are highly interactive and the best information writers routinely import techniques of experiential writing into their craft to enliven and layer the reader's experience. Technologies for making visible for students their tacit decision-making over hundreds and thousands of compositional moves when writing experience and information are introduced and provide students a literal "lens" on the texts they write as an endlessly curious design artifact.

76-796 Non-Profit Message Creation

Intermittent
Non-profit organizations support a multitude of causes ranging from the arts to animals to the environment to health care to human rights to scientific research to many great causes in between. Non-profits achieve their missions by advocating on behalf of their organization's cause, raising public awareness about issues surrounding their cause, and fundraising to make their advocacy possible. In this course, students will select a local, Pittsburgh-area non-profit to examine and produce materials based on the organization's needs. Over the course of the semester students will research the organization's persona and values via interviews with chosen organization's staff and analysis of existing communication channels and different forms of content currently used by the organization. Students will use this research and analyses to inform and shape a final project that should meet the specified, needed deliverables from the selected non-profit. Previous example projects include: Revising a newsletter and specifying future best practices for an organization; developing new format and copy for an organization's website; developing a social media campaign for an upcoming event; developing a grant proposal for an organization's project; among many others. Students will have a wide selection of organizations to choose from and know projects associated with the organization at the beginning of the semester, as these will be organized by the professor. At the end of the course, students will have a portfolio ready material and an increased understanding as to how non-profit organizations advance their causes.

Course Website: http://www.cmu.edu/dietrich/english/index.html (http://www.cmu.edu/dietrich/english/)

76-805 Institutional Studies: English as a Discipline

All Semesters: 6 units
While literature has existed for centuries, the discipline of literary studies is relatively new, only forming in the late 19th century and not coalescing until after World War II. This course will look at the history of the discipline of literary studies, from its roots in scholarly methods like philology, to its expansion into cultural studies. We'll read some key texts, such as Gerald Graff's Professing Literature, and critiques by Richard Ohman and many contemporary critics.

76-807 Topics in Literary & Cultural Studies

All Semesters
Topics vary by semester. Spring 2022: There Are Black People in the Future. In 2018 the African American artist and CMU professor, Alisha Wormsley created a slogan for a billboard in Pittsburgh's East Liberty that read: THERE ARE BLACK PEOPLE IN THE FUTURE. The billboard had featured many artists and slogans over a period of years, but this one was taken down when the building's landlord objected to the content. The controversy over this piece of art gives this course its name. There are black people in the future, and there are extraordinary black artists in Pittsburgh at this very moment. This special topics course will consider what some are calling a new Pittsburgh Renaissance in the black arts, from art to literature to film and music. Featured writers include Deesha Philyaw, The Secret Life of Church Ladies, Brian Broome, Punch Me Up To The Gods, and Damon Young, What Doesn't Kill You Makes You Blacker. We will also look at the work of the writer Jason England, the artists Alisha Wormsley, Vanessa German, Devan Shimoyama, the rapper Jasiri X, and the film maker Chris Ivey. An in depth look at these artists will be paired with an examination of the history of African Americans in Pittsburgh, and current economics, sociology and politics surrounding race in the city.

76-808 Culture and Globalization

Intermittent
We are often told we live in a period of globalization, but what that means differs widely. Theories of globalization describe such diverse processes as international capital and markets, neo-liberalism and neo-colonialism, environmental devastation, transnational labor and migration, modernity, shifts in spatial and temporal relations, cosmopolitanism, global cultural production and consumption, and the resurgence of nationalism. In this course we will explore and historicize the concept of globalization from both a global literary perspective and an interdisciplinary lens. Pairing literary works from around the world with scholarship from sociology, political science, gender and critical race studies, and anthropology, we will examine the contradictions, conflicts and possibilities of associated changes in the world. We will investigate the role of representation and aesthetics by considering the work of literary writers as well as some filmmakers, journalists and activists. The course will be organized as a series of topical foci that might include neoliberalism and labor, the local and the global, environmental changes, secularism and tradition, the globalization of feminism, and global migration and border control.

76-813 Book Design: A Cultural History

All Semesters: 12 units
Today the book is thriving despite earlier predictions of its "death" at the hands of the digital media. What has made the book so powerful a medium over six centuries? This course will take you into the book's makeup, design, and impact over time. We study how the book was made at different times in its historyfor instance, the manuscript book (medieval), the hand-press book (Renaissance and eighteenth century), the machine-made book (1800s to present). We also ask how today's databases like Google Books make us see new dimensions of the print medium that were not visible earlier. Likewise we will study theories of the print medium and the cultural effects of the book among readers and social groups. Students will have hands-on experience with a printing press and the Rare Book archives at Hunt and Hillman libraries. Two papers and shorter assignments will be required.

76-818 Rhetoric and the Body

Intermittent
This course offers an introduction to rhetorical studies of the body and is centered on the following three questions: What is the role of the body in rhetorical theory? What role does rhetoric play in constructing the body as a raced, gendered, dis/abled, cultural, fleshy, and political entity? And, how might moving, feeling bodies challenge, regulate, or disrupt these rhetorical constructions and furthermore, our theories of rhetoric? Our readings will explore the role of embodiment in rhetorical theory, examining a number of contemporary and historical theories of the body. In the process, we will explore how to put rhetoric and the body into conversation with one another and what methodological implications this conversation has for rhetorical studies more broadly. The goal of this course is to provide breadth rather than depth, with the assumption that most students, even those relatively familiar with body and/or rhetorical theory, will approach rhetorical studies of the body as novices. Students will conduct their own research on a topic related to rhetorical studies of the body that also aligns with their professional and academic goals. Graduate students interested in research will benefit from this course's focus on theory and the professional genres central to rhetorical studies. Undergraduates students (both majors and non-majors) will have the opportunity to examine how the body intersects with communication and writing contexts in their everyday public and professional lives. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-822 Intro to Gender and Sexuality Studies

Intermittent: 6 units
This graduate-level course offers students a scholarly introduction to theories of gender and sexuality. In this class, we will use intersectional approaches to consider gender theories, feminist theory, masculinity studies, queer theory and scholarly discussions of sexuality. Readings will include Kimberl and #233; Crenshaw, bell hooks, Judith Butler, Raewyn Connell, Sara Ahmed, Eve Sedgewick, and Jasbir Puar, among others.

76-825 Rhetoric, Science, and the Public Sphere

Intermittent
In the 21st century science and technology are ubiquitous presences I our lives. Sometimes these phenomena spark our imagination and affirm our confidence in a better future. In other instances, they create fear and generate protests over the risks new technologies and scientific ideas pose to prevailing social, cultural, economic, and political orders. In this course we will examine the complex dynamics in the relationships between science, technology, and society. Towards this end we will engages with questions such as: How do we decide who an expert is? To what extent do scientists have an obligation to consider the social and ethical consequences of their work? Is public education about science and technology sufficient for addressing social concerns about risk and controversial scientific ideas? We will grapple with these and other questions by exploring public debates including conflicts over global warming, vaccinations, and the AIDS crisis. With the help of analytical theories from sociology, rhetoric, and public policy, we will develop a framework for thinking about argument and the dynamics of the relationship between science, technology, and the public. We will also look to these fields for tools to assess public debate and to complicate and/or affirm prevailing theories about the relationship between science and society.

76-829 Introduction to Digital Humanities

Intermittent
This course is a "learn by doing" introduction to questions and methods in digital humanities, with special emphases on common tasks in digital history, digital literary studies, library science, and cultural analytics. Students will likely partner with a national humanities organization to tackle real-world humanities problems while developing core computational competencies such as those required for gathering data (text mining, APIs), transforming data (OCR, regular expressions, natural language processing, image magick), file management (shell commands), data visualization (matplotlib, arcGIS), and more.

Course Website: http://www.cmu.edu/dietrich/english/index.html (http://www.cmu.edu/dietrich/english/)

76-831 Gender Play in Early Modern Drama

All Semesters: 12 units
The playhouses of early modern London offered access to an astonishing spectacle that would be difficult to find anywhere else in the city: men dressed as women, skillfully reproducing (but also exposing, interrogating, and refining) the significations that structure concepts of gender difference. In addition to this fundamental condition of performance and theatrical experience, the plots of the plays themselves regularly engaged with issues pertaining to gender and sexuality, an interest that runs through the raunchy satires performed by companies of adolescent boys, the innumerable comedies of cross-dressing and mistaken identity, and the equally numerous tragedies centered on problems of inequality and imbalances of power. This course will consider a wide range of drama from the period alongside a selection of readings in sexuality and gender theory, thus bringing early modern dramatists such as William Shakespeare and Thomas Middleton into conversation with contemporary thinkers such as Judith Butler and Sarah Ahmed. The body of core texts will include Twelfth Night, The Merchant of Venice, As You Like It, The Roaring Girl, The Taming of the Shrew, The Tamer Tamed, The Island Princess, The Witch of Edmonton, The Silent Woman, Women Beware Women, and Galatea.

76-833 Historicisms

All Semesters
What is a critical historicism? What theories of history, texts, and social life have been driving literary and cultural scholarship since the late twentieth century? What is the ongoing tension between historical accounts of literature/culture? This course will introduce students to ways of thinking about how literary and cultural texts or genres can be studied historically, whether they were written in the early modern age or the twentieth century. We will especially explore controversities about methods of studying texts in history and #8212;about historicism vs. presentism, the relation of text and context, periodization, longue dur and #233;e, reception history, transhistorical meanings. Readings will include Walter Benjamin, Karl Marx, Michel Foucault, Jack Halberstam, Stephen Greenblatt, Judith Newton, Joan Scott and others.

76-844 History of Books and Reading

Fall
Rather than putting an end to the book, digital media have had the oddly exhilarating effect of making us look at all kinds of print, past and present, through newly focused lenses. This course will introduce you to the history of books and reading, a cross-fertilizing field of study that is having an impact on many disciplines, from the history of science to literary history, cultural studies, and the arts. Scholarship in this still-emerging field will include work by Roger Chartier, Michel Foucault, Elizabeth Eisenstein, Pierre Bourdieu, Michel de Certeau, , and the current scholars who appear in one of our key books, "Interacting with Print: A Multigraph." We'll also read primary texts by Joseph Addison, Jane Austen, Samuel Coleridge, and Wilkie Collins to see how differing modes of print and reading became highly contested cultural and political matters in the eighteenth and nineteenth centuries. Other topics include the division between new reading publics and their ways of reading books; important changes in book production, typography, printing methods (hand-press to steam press). Such knowledge of the history of print has become especially crucial in an era of emerging "new media" and the field of digital humanities in the university. Two papers will be requiredone shorter paper (5-7 pp.) and a longer research paper on the uses of books and print by producers and readers. Though the course meets in Baker Hall, you will have hands-on experience with early books and other forms of print as we also meet periodically in the Rare Book Room at Hunt Library.

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-846 Revenge Tragedy

All Semesters
Attendants to the early modern English theater seem to have had an almost insatiable appetite for revenge tragedy: a lurid, blood-soaked genre distinguished by plots involving insanity, skulls, ghosts, poisonings, stabbings, suicide, and other forms of unnatural death. This course will cover key examples of the genre, putting particular emphasis on the depiction and interrogation of justice, analyses of death, and playful engagement with theatricality. Our central curriculum will include the following plays: Thyestes (Seneca), The Spanish Tragedy (Kyd), Titus Andronicus (Shakespeare), Hamlet (Shakespeare), The Revenger's Tragedy (Middleton), and The Duchess of Malfi (Webster). We will also read a selection of critical essays and related literature from the period.

76-849 Race and Media

Intermittent
This course will introduce students to useful methodological approaches to analyze race and representation within a variety of media formats. Media in this course is understood broadly: technologies used to store and deliver information. With this rather broad understanding in mind our course will look at how artists and intellectuals use discrete formats (print, film/video, electronic, and other recording mediums) to imagine, remediate and study the circulation of racialized bodies and identities within global capitalism. We will also think about the concept of race itself as another, particularly problematic "media" format used to store and deliver information about the human for political, economic, ideological and juridical purposes. The class will be organized around specific material and "immaterial" media objects that will allow us to explore the processes of (re)mediation that characterize racialized bodies and formats. We will look at a range of formats from literature and music to film, television, and social media. The course is structured to provide both a chronological and historicist approach to the discourses that define race and media. More than likely, we will watch and (or) read the works of D.W. Griffith, Nella Larson, Melvin Van Peebles, Lizzie Borden, Audre Lorde, Claudia Rankine, Alex Rivera and Nia DaCosta. We will also read the theoretical works of Jacques Ranciere, Huey P. Newton, Dallas Smythe, Lisa Gitelman and Michael Gillespie, Simone Browne, Theodore Adorno, Sara Ahmed and many others.

76-850 Law, Culture, and the Humanities

Intermittent
"I'm not a lawyer, but..." How many times have you heard this disclaimer, closely followed by a lay analysis of law? This course, an introduction to the cultural study of law for graduate students and advanced undergraduate students, can be seen as an introduction to what goes into the making of such a statement. Where do we get our ideas about law? What do we mean when we say "law"? What counts as law? How does culture influence law, and law, culture? And to what degree should historical context condition any answers we might be tempted to give? Students in the course will study works in a range of genres (novels, plays, poems, judicial opinions, pamphlets) and develop methods for investigating ways that law and culture have been made by one another from the 16th-century to the present. Readings will include influential theoretical accounts of law (Aristotle, Hobbes, Cover, Habermas, Bordieu, MacKinnon, Alexander), canonical texts in Law and Literature (Shakespeare's Measure for Measure, Melville's Billy Budd, Kafka's The Trial) and some "weird fiction" by the novelist/legal theorist China Mi and #233;ville. As a counterpoint to the fiercely anti-historical "law and economics" movement, however, the course will put special emphasis on rooting intersections of law and culture in rich historical context, considering both local and international legal contexts (sometimes in fairly technical detail) alongside so-called "ephemera" of culture. Students will tackle the especially fruitful "case" of Renaissance Britain before developing final research projects, whether on the Renaissance or another period of their choosing.

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-852 Generations and Culture

Intermittent
We frequently hear about generations and #8212;the Millennials and their multitasking, Gen X and their minivans, and the Baby Boomers and their self-satisfaction and #8212;but generations have usually been ignored in cultural studies. Yet generations have significant impact on cultural tastes, consumer choices, and political views, as a good deal of research shows, and identity, alongside other factors such as race, class, gender, sexuality, ethnicity, and abledness. This course will study the theory of generations, as well as novels and films that tell us about generations.

76-853 Literature of Empire

Fall
Nineteenth and early twentieth-century British literature was shaped by events taking place outside as well as inside of national borders. Even in the eighteenth and nineteenth centuries, with international trade and slavery supporting the manor house and plantations abroad providing the cotton for British looms, the "England" of English literature spanned the globe. By the first half of the twentieth century, this empire had begun to collapse in upon itself, a process witnessed by writers inside Britain and its colonies. This course will investigate British literature within the international context of global imperialism. A section on gothic stories takes us into the realm of popular culture with Mary Shelley's Frankenstein and Arthur Conan Doyle's short stories. We take to the seas with Joseph Conrad's Lord Jim, before we consider W. Somerset Maugham's exploration of sexuality in the tropics in The Painted Veil. Finally, we return to England to outline the links between colonial empire and international war rendered in Virginia Woolf's Mrs. Dalloway. These literary works will be read alongside some of the most important works of postcolonial theory. While course readings focus on 19th and early 20th century, student's will undertake a research project over the semester in their own period of interest in British literature in connection with empire studies.

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-854 Introduction to Literary and Cultural Studies

Fall
Cultural Studies is an intellectual and professional movement identified with the Center for Contemporary Cultural Studies in Birmingham. This movement grew out of literary studies. It is neither identical with literary studies, nor opposed to literary studies. It is today one form that the study of literature or other cultural works may take. This course offers a theoretical genealogy of cultural studies, showing how and why its theories and practices emerged and developed. As a genealogy, the course does not assume that cultural studies has an essence or an origin. The texts and topics will reflect the heterogeneity of its emergence and development. The course does, however, embody what we see as several historical changes in cultural studies, from idealism to materialism, from mono to multiculturalism, and from high culture exclusiveness to democratic inclusivity. The course is not designed to teach "approaches," but to explore and interrogate the founding assumptions of the academic project that you are being trained to join. Students should, by the end of the class, have a sense of where cultural studies came from and of the problems and possibilities raised by the theories it continues to invoke.

Course Website: http://www.cmu.edu/dietrich/english/index.html (http://www.cmu.edu/dietrich/english/)

76-864 Creative Nonfiction Workshop

Fall
Narrative Medicine looks at the intersection of writing and healing. How does narrative help heal the mind, and how are the mind and body inextricably linked? The couse will introduce you to several books and essays centered around the theme of wellness and illness and #8212;- and how these modes of being are represented and shaped by culture. You will write your own personal essays on these topics along with a final research paper. A great class for anyone interested in the power of story-telling in our own lives.

76-867 Crime Fiction and Film

Intermittent: 12 units
This course will be concerned with hardboiled crime fiction in print and on screen. The hardboiled emerges in Ernest Hemingway a distinctive literary style, and about same becomes a formula for pulp crime fiction. The language and attitude of the hardboiled became associated with urban gangsters in films such as The Public Enemy. Newspaper crime coverage beginning in the 1920s becomes increasingly frank in both its language and photographic coverage of crime. These various elements will be the material for a new kind of literature represented Dashiell Hammett, James M. Cain, and especially Raymond Chandler, and for a cycle of films that owe much to their work, film noir. Chandler was responsible for invention of one of most enduring types in American fiction, the hardboiled detective. The course will focus on Chandler and the crime stories after him that make various uses of that type and the formula that has become associated with it. Throughout the course we will consider the social and political contexts in which these cultural forms developed, and what cultural work the hard-boiled performed. We will be especially interested such questions as the function of the misogyny typical of much of it, the different representations of race by white and black artists, the representation of police, whether the hardboiled is best understood as having a working-class affiliation, and the degree to which its various manifestations might be called realist.

76-868 Space and Mobilities

Intermittent
This course will investigate space and movement as social constructions. Space is something dynamically created that may be interpreted for the ways it creates meaning, while movement reproduces and constitutes power and institutions. This interdisciplinary course considers theories of space and movement as a field of study and in reference to literary and film texts. The course might include discussions of migrants and state borders, cultural constructions of transport, the poetics of space, and the dynamic mapping of the city through movement and sound. Readings might include Henri Lefebvre, Doreen Massey, Edward Soja, Gaston Bachelard, Wendy Brown, John Urry, Tim Cresswell, Marian Aguiar; literary texts might include Brian Friels Translations, Christina Garcia's Dreaming in Cuban, W.G. Seabald's Austerlitz and Teju Cole's Open City. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission. Students across disciplines are encouraged and may work on a final project related to their primary field.

76-870 Professional and Technical Writing

Fall
This course is an introduction to the theory, research, and practice of professional and technical communication as a discipline. Through readings, discussions, projects, and writing workshops, you will develop a rhetorically-grounded approach to analyzing communications problems and producing a range of effective and situation-specific professional documents. This user-centered approach views professional documents as means to accomplish specific, well-defined purposes: getting funding or support for a project (proposals), supporting managerial decision-making (reports), communicating effectively within organizations (email, correspondence), guiding action (instructional writing), getting a job or internship (resumes and application letters), or making choices among various medical treatments (science writing for general audiences). Because writers need a range of skills that go well beyond the actual inscribing of words on a page, you also gain practice in how to test documents on actual users, edit and revise your own work and that of other writers, and participate in and manage collaborative writing projects. The course features three major writing assignments. Core course for MAPW students.

Course Website: http://www.cmu.edu/dietrich/english/index.html (http://www.cmu.edu/dietrich/english/)

76-881 Introduction to Multimedia Design

Fall: 12 units
This class meets the increasing demand for professional/technical writers who understand multimedia and its communicative possibilities. It provides students with the opportunity to create both an explainer video and a more persuasive animation merging text, spoken voice, music, images, and video clips. Students will learn the basic concepts and vocabulary of motion graphics, practical issues surrounding designs that change over time, and digital storytelling through hands-on projects. Inspiration is drawn from popular Vox and Ted Ed explainer videos that have come to represent the genre. Students explore writing and recording their own narration and how to best utilize elements of time, motion, and sound to enhance their visual communication skills. Adobe After Effects will be taught to complete assignments and explore multimedia possibilities. Some Adobe Photoshop, Illustrator, and Audition will also be taught to support specific tasks. Basic experience with Photoshop or Illustrator prior to taking this class is helpful, but not required. In-class discussions and critiques are essential components of the course.
Prerequisites: 76-391 or 51-262 or 76-791

Course Website: http://www.cmu.edu/dietrich/english/index.html (http://www.cmu.edu/dietrich/english/)

76-884 Discourse Analysis

Fall
This course teaches an empirical and systematic approach to analyzing texts. The central question we ask is this: how does language shape contexts and how do contexts, in turn, shape language? We typically focus on micro-linguistic elements, but also examine visual aspects of texts.

Course Website: http://www.cmu.edu/dietrich/english/index.html (http://www.cmu.edu/dietrich/english/)

76-885 The New Public Sphere

Fall
Public deliberation about issues that matter to us is at the heart of the rhetorical tradition. But is meaningful public dialogue really a live option in a divisive, media-saturated world of sound bites addressed to partisan publics? Moreover, is the process of debate, deliberation, and decision making (in which the best argument wins) really the normal (or even ideal) model? Or can people use local public spaces to develop new, more inclusive positions? How might such a process create a boundary-crossing public in which diverse groups enter intercultural deliberation around racial, social, economic or environmental issues? This course looks at critical ways people use rhetoric to take literate social action within local publics. From the debate spurred by Habermas's canonical version of the public sphere, we move to a feminist "rereading" of the Greek Sophists, to more contemporary studies of deliberation in workplaces, web forums, grassroots groups, new media, and community think tanks. Working as a rhetorical consultant into the meaning making process of a local public of your choice, you will also learn how to support your inquiry with a variety of methods, from an interactive activity analysis to a more focused probe into the social/cognitive negotiation conflict may require.

Course Website: http://www.cmu.edu/hss/english/courses/courses.html

76-891 Rhetorical Analysis

Fall and Spring
Students in this course will learn various approaches to analyzing discourse artifacts from a rhetorical point of view. Early in the course, students will identify an artifact or artifacts they wish to analyze. From there, students will be encouraged to explore their own methods of analysis based on two required books for the course and reviews of literature. For the midterm, students will create an annotated bibliography of five specimens of criticism taken from a single journal. For the final project student will first present and then hand in a polished 15 page piece of criticism based on one or some combination of methods. The presentation and final paper count 50% of the grade, with the mid-term, class attendance, participation, and homework making up the final 25%.

76-893 Introduction to Global & Postcolonial Studies

Intermittent: 6 units
Since the 1978 publication of Edward Said's groundbreaking work Orientalism, postcolonial theory has gained currency as a critical discourse examining global experiences of colonization and decolonization. Since the term "postcolonial" was first invoked to describe the cultural effects of colonization, the field of study has expanded considerably. Today postcolonial studies looks backwards at earlier works on nationalism and cultural identity, gazes forwards towards seemingly dire futures, and unpacks present conjunctures. In this course, we will follow several threads of postcolonial theory to talk about the discursive operations of empire, the politics of representations, the problems of nationalism, the intersections of race, gender and sexuality in a global context, and the effects of colonialism, imperialism and globalization on economies, ecology, climate, and migration.

76-894 Digital Humanities

Intermittent: 6 units
Digital Humanities is an emerging discipline as well as a broad collection of scholarly activities that apply new technologies to humanities research while expanding traditional forms of scholarly communication. Some of its many facets include: book history, cartography (using maps to better understand the cultural production of texts), the preservation and sharing of collections that are otherwise difficult to access. DH can also include the fostering of new creative expression by using digital media. In this mini we'll be reading a variety of leaders in the field including Robert Binkley, Franco Moretti, Matthew Jockers, Peter deBolla, Johanna Drucker, Alan Liu, Jerome McGann, Christopher Warren, and Bethany Nowviskie, attending the CMU DH lunch workshops, and taking some field trips around the city to see some DH projects in action.

76-896 Research Methods in Rhetoric & Writing Studies

All Semesters
This course is a survey introduction to historical, empirical, text-based, and qualitative methods of inquiry used in the fields of rhetorical and writing studies. We will read broadly to understand the philosophical questions, research traditions, practical applications, and innovative directions that shape the field, exposing students to a range of methods and methodologies. Studies of rhetoric, writing, and literacy have evolved tremendously, and we will examine approaches for how to trace, analyze, and critique the use of meaning making in a variety of cultural, political, workplace, technological, and pedagogical contexts. By the end of the course, students will develop a sense of how to put together an effective research project on their own and design and articulate the research methods and methodologies appropriate to that study. Throughout, we will ask a fundamental question: How do rhetoric, writing, and literacy work and for what consequences?

Department of History

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Undergraduate Degree Options in the Department of History

The B.A./B.S. in Social & Political History

The B.A. in Global Studies

The B.A./B.S. in Ethics, History, and Public Policy

The Department of History offers undergraduates a choice of three majors: Social & Political History, Global Studies, and Ethics, History, and Public Policy. Specific requirements and courses for each major are detailed below.

All three History majors are grounded firmly in the liberal arts. Each has a strong interdisciplinary bent and an equally strong commitment to using knowledge of the past to illuminate present-day social, cultural, and political affairs.

In different ways, all three majors emphasize empirical research methods and conceptual analysis, and cultivate reading, research, and writing abilities central to a variety of professions. Our students develop strong analytic and writing skills; choose among diverse U.S., global, and thematic courses; learn experientially through internships and/or study abroad; and benefit from small class sizes and easy access to faculty who are internationally known for innovative historical, anthropological, and other social science approaches to investigating the past. The study of history necessarily includes diverse societies and controversial public policy issues, usefully blending liberal education with professional development.

History is also excellent preparation for leadership positions in law, business, journalism, politics, education, and government service (e.g., U.S. Foreign Service, Health & Human Services, Federal Trade Commission). The resumes of innumerable CEOS and government statesmen show how effectively the study of history serves as a foundation for preparing leaders both at home and abroad.

Having been trained to analyze subtle and complex issues, to develop breadth of understanding, to dig out information and make sense of it, and to present their findings effectively, graduates of the History Department do extremely well in many types of for-profit, non-profit, governmental, and non-governmental organizations. Because history training combines research and writing skills with analysis of social and policy trends, it also prepares graduates for journalism and other writing careers in the modern media age.

All three History degree programs combine easily with majors in Business, Economics, English, Information Systems, Languages, Cultures, and Applied Linguistics, Philosophy, Professional Writing, Social and Decision Sciences, and Statistics.

Additional Majors

The majors in Social & Political History, Global Studies, and Ethics, History, and Public Policy may be declared as additional majors in consultation with the Academic Program Manager, Dr. Alexandra Garnhart-Bushakra. You can reach Dr. Garnhart-Bushakra in the History Department, Baker Hall 240G to schedule a meeting with her directly.

Interdepartmental Majors

In addition to the Ethics, History, and Public Policy major, History faculty are also integral participants in interdepartmental majors described elsewhere in this catalog: International Relations and Politics in the Institute for Politics and Strategy, and the Languages, Cultures, and Applied Linguistics Department.

Minors

Options for pursuing a minor in Social & Political History or Anthropology are discussed below, following the sub-section on Ethics, History, and Public Policy.

Several other minors with strong History content, detailed elsewhere in the Undergraduate Catalog, can be linked with any degree. Students should contact the relevant History faculty members listed below:

- African and African American Studies: Professor Edda Fields-Black (fieldsblack@cmu.edu)
- Environmental and Sustainability Studies: Professor Abigail E. Owen (aeown@cmu.edu)
- Gender Studies: Professor Lisa M. Tetrault (tetrault@andrew.cmu.edu)
- Religious Studies: Professor Allyson F. Creasman (allysonc@andrew.cmu.edu)
- Russian Studies: Professor Wendy Goldman (goldman@andrew.cmu.edu), Professor Tatyana Gershkovich (tgershko@andrew.cmu.edu)
- Science, Technology, and Society: Professor Christopher J. Phillips (cjp1@cmu.edu)

Research and Outreach Centers

History Department faculty members lead three research and outreach centers that advance new interdisciplinary knowledge and help translate knowledge into public policies that further the pursuit of social, economic, and political justice.

1. CAUSE (Center for African American Urban Studies and the Economy), Joe W. Trotter, Director
2. The Bajaj [India] Rural Development Lab, Nico Slate, Director
3. The Center for Human Rights Science, Jay D. Aronson, Director

The Major in Social & Political History (SPH)

Professor Ricky Law, *Director of Social & Political History and Director of Undergraduate Studies*, History Department
Location: Baker Hall 238B, 412-268-2880, rlaw@andrew.cmu.edu

Dr. Alexandra Garnhart-Bushakra, *Academic Program Manager*, History Department
Location: Baker Hall 240G, 412-268-1260, agarnhar@andrew.cmu.edu

www.cmu.edu/dietrich/history/undergraduate/sph (https://www.cmu.edu/dietrich/history/undergraduate/sph/)

Social & Political History (*SPH*) is a research- and writing-intensive major that emphasizes analysis of change over time and in-depth understanding of the societies, cultures, economies, political systems and conflicts that have shaped our world. History electives focus on areas of faculty expertise such as science, technology, race, culture, public health, environment, gender, labor, war, politics, sports, education, and criminal justice.

All majors take Introduction to Historical Research & Writing (79-200, 9 units) and the capstone Historical Research Seminar (79-420, 12 units), where they conduct individualized projects using archival and other primary sources. Several students have published the results of their research, and we are exploring new ways to facilitate future publication of students' research in both undergraduate and professional history journals.

The broad analytic, research, and writing skills cultivated by the SPH major prepare students for success in a wide variety of graduate and professional schools, and for exercising leadership in careers in business, law, government, education, journalism, public policy, social work, the armed services, Foreign Service, media, museums and libraries. Often, history graduates pursue post-undergraduate professional school, such as law, business administration, education, public policy, urban planning, librarianship, journalism, the ministry, and social work.

For students interested in pursuing a professional career in History, options today include not only research and teaching -- our graduates have earned Ph.D. degrees at Harvard, Northwestern, and other major universities -- but also expert positions as historians in museums, archives, historic sites, the armed services, media outlets, and other public history venues.

Students graduating with a primary major in Social & Political History may pursue a B.A. or B.S. degree. *SPH* may also be taken as an additional (i.e., second) major.

Curriculum (93 units)

All students in the Social & Political History major are required to complete two research-training courses: Introduction to Historical Research & Writing (79-200, 9 units), and Historical Research Seminar (79-420, 12 units), which is regularly offered in the Fall semester of the senior year. Students must earn a final grade of “C” or better in these two courses in order to fulfill the requirements for the *SPH* major.

Students in the Social & Political History major are also required to take at least one of the following general education courses: Genocide and Weapons of Mass Destruction (79-145, 9 units) Introduction to the History of Science (79-160, 9 units), or Democracy and History: Thinking Beyond the Self (79-189, 9 units).

In addition, students must take two historical *survey courses* from a wide range of attractive options that include most major regions of the world.

Otherwise, students enjoy great flexibility: they are free to take additional survey courses or to specialize in thematic topics or regions of the world that are of special interest to them.

If you are interested in pursuing a minor in SPH, please view the section (see below) for the Minor in Social and Political History.

Social & Political History Major (*SPH*)

I. Required General Education Course (9 units)

79-145	Genocide and Weapons of Mass Destruction	9
79-160	Introduction to the History of Science	9
79-189	Democracy and History: Thinking Beyond the Self	9

II. Required History Department Courses (21 units)

79-200	Introduction to Historical Research & Writing	9
79-420	Historical Research Seminar	12

III. Required Survey Courses (*choose two* -- 18 units)

79-120	Introduction to African American History: Black Americans and the World	9
79-170	Introduction to Science, Technology, and Society	9
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-203	The Other Europe: The Habsburgs, Communism, & Central/Eastern Europe, 1740-1990	9
79-204	American Environmental History	9
79-205	20th Century Europe	9
79-206	Crime and Punishment in Early Modern Europe	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-212	Jim Crow America	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-225	West African History in Film	9
79-226	African History: Earliest Times to 1780	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-229	The Origins of the Palestinian-Israeli Conflict, 1880-1948	9
79-230	The Arab-Israeli Conflict and Peace Process Through 1948 to Present	9
79-240	Development of American Culture	9
79-242	African American History: Reconstruction to the Present	9
79-244	Women in American History	9
79-245	Capitalism and Individualism in American Culture	9
79-248	U.S. Constitution & the Presidency	9
79-249	20th Century U.S. History	9
79-250	Voting Rights: An Introduction	9
79-255	Modern Ireland: Politics and Culture from the Famine (1847) to Today	9
79-260	Nazi Germany	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-265	Russian History: Game of Thrones	9
79-266	Russian History and Revolutionary Socialism	9
79-269	Russian History: From Socialism to Capitalism	9
79-272	Coexistence and Conflict: Muslims, Christians and Jews in Spain and Portugal	9
79-282	Europe and the World Since 1800	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-320	Women, Politics, and Protest	9

IV. Social & Political History Elective Courses (45 units)

Students must complete 45 elective History units (*typically 5 courses*) for the Social & Political History major. Any History Department courses not fulfilling another major requirement may be chosen as an elective.

Social & Political History majors have considerable flexibility in choosing their elective courses, but should consult with the Academic Program Manager, Dr. Alexandra Garnhart-Bushakra, History Department, Baker Hall 240G, in making their selections.

For a complete list of elective course options in History, please consult the History course descriptions elsewhere in this catalog. The selections below are designed to give you a sense of the great variety of thematically centered courses (in addition to the survey courses listed earlier) that History Faculty members regularly teach:

79-112	Introduction to Asian American History	9
79-175	Moneyball Nation: Data in American Life	9
79-201	Introduction to Anthropology	9
79-207	Asian American History through the Novel	9
79-208	Witchcraft and Witch-Hunting	9
79-216	Genghis Khan and the Mongol Empire	3
79-218	Tiananmen Square and Popular Protest in Modern China	6
79-219	Hong Kong, Taiwan and the Idea of "China"	6
79-220	Screening Mexico: Mexican Cinema, 1898 to Present	6
79-222	China and the Second World War	6
79-234	Technology and Society	9
79-237	Comparative Slavery	9
79-243	The Civil War in American Memory	6
79-246	Industrial America	9
79-247	African Americans, Imprisonment, and the Carceral State	9
79-252	"Harriet": Harriet Tubman, Slavery, and the Underground Railroad	6
79-257	Germany and the Second World War	9
79-256	Sex, Guns, Rock, and Skinheads: Youth Rebellion in Europe, 1960-1990	9
79-260	Nazi Germany	9
79-263	Mao and the Chinese Cultural Revolution	9
79-264	Tibet and China: History and Propaganda	9
79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-268	World War I: The Twentieth Century's First Catastrophe	9
79-270	Anti-Semitism Then and Now: Perspectives from the Middle Ages to the Present	9
79-273	Jews and Muslims in History	9
79-276	Beyond the Border	9
79-278	How (Not) to Change the World	9
79-280	Coffee and Capitalism	9
79-283	Hungry World: Food and Famine in Global Perspective	9
79-289	Animal Planet: An Environmental History of People and Animals	9
79-290	The Slave Passage: From West Africa to the Americas	9
79-292	China and the West	9
79-297	Technology and Work	9
79-298	Guns, Gun Cultures, and Gun Violence in American History	6
79-300	Controversial Topics in the History of American Public Policy	9
79-301	History of Surveillance: From the Plantation to Data Capitalism	6
79-302	Killer Robots? The Ethics, Law, and Politics of Drones and A.I. in War	9
79-303	Pittsburgh and the Transformation of Modern Urban America	6

79-309	The Chinese Revolution Through Film (1949-2000)	9
79-313	"Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration	6
79-314	How Do We Remember? The Politics and Cultures of Memory	9
79-315	The Politics of Water in Global Perspective	9
79-316	Photography, the First 100 Years, 1839-1939	9
79-317	Art, Anthropology, and Empire	9
79-318	Sustainable Social Change: History and Practice	9
79-319	India Through Film	6
79-322	Stalin and the Great Terror	9
79-324	#MeToo: Naming and Resisting Gender Violence	6
79-326	Shall We Dance? Culture, Politics, and Movement in the 20th Century	6
79-328	Photographers and Photography Since World War II	9
79-330	Medicine and Society: Health, Healers, and Hospitals	9
79-331	Body Politics: Women and Health in America	9
79-337	Educational Policy and "School Choice": Historical and Contemporary Perspectives	6
79-338	History of Education in America	9
79-339	History of Juvenile Delinquency & Juvenile Justice	9
79-340	Juvenile Delinquency & Film: From "Boyz N the Hood"(1991) to "The Wire"(2002-08)	6
79-342	Age of Crusading, 1000-1800	9
79-343	Education, Democracy, and Civil Rights	9
79-345	Roots of Rock & Roll	9
79-346	U.S. Political Films and Satire	9
79-350	Early Christianity	9
79-352	Christianity Divided: The Protestant and Catholic Reformations, 1450-1650	9
79-357	Science and the Body	6
79-359	Truth, Lies, and Propaganda: A Historical Inquiry	9
79-360	Crime, Policing, and the Law: Historical and Contemporary Perspectives	9
79-363	The Rise of American Modern Golf, 1895 to the Present	9
79-368	Un-natural Disasters: Societies and Environmental Hazards in Global Perspective	6
79-371	African American Urban History	9
79-372	The Rise and Fall of Pittsburgh Steel	6
79-373	Culture and Revolution: The Socialist Experiment in Soviet Russia	6
79-377	Food, Culture, and Power: A History of Eating	9
79-379	Extreme Ethnography	9
79-380	Hostile Environments: The Politics of Pollution in Global Perspective	9
79-383	The History of Capitalism	9
79-385	Out of Africa: The Making of the African Diaspora	9
79-387	General Francisco Franco: Fascism and its Legacies in Spain	6
79-394	Exploring History through Geography	6
79-395	The Arts in Pittsburgh	9

Social & Political History Major — Sample Curriculum

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
79-145 Genocide and Weapons of Mass Destruction or 79-189, Democracy and History: Thinking Beyond the Self	SPH Survey Course	SPH Survey Course	SPH Elective Course
First-Year Writing Requirement	36-200 Reasoning with Data	General Education Course	General Education Course
Grand Challenge Seminar	General Education Course	General Education Course	Third Course (open)
General Education Course	Fourth Course (open)	Fourth Course (open)	Fourth Course (open)
General Education Course	Fifth Course (open)	Fifth Course (open)	Fifth Course (open)
99-101 Core@CMU			

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
79-200 Introduction to Historical Research & Writing	SPH Elective Course	79-420 Historical Research Seminar	SPH Elective Course
SPH Elective Course	SPH Elective Course	Second Course (open)	Second Course (open)
General Education Course	General Education Course	Third Course (open)	Third Course (open)
General Education Course	Fourth Course (open)	Fourth Course (open)	Fourth Course (open)
Fifth Course (open)	Fifth Course (open)	Fifth Course (open)	Fifth Course (open)

The table above represents a four-year plan for completing all requirements for the Social & Political History Major. Students may declare the major and begin course requirements as early as the start of the sophomore year and in some instances in the freshman year. Students should meet with the department's Academic Program Manager, Dr. Alexandra Garnhart-Bushakra, Department of History, Baker Hall 240G, for both short- and long-term course planning.

*Some Social & Political History majors choose to apply for the senior honors thesis program. The department strongly encourages students to take advantage of this option.

V. Courses in Other Departments that Satisfy SPH Elective Requirements (*up to 27 units*)

Students may satisfy the elective requirements in SPH with *up to 27 units* of the following courses offered by other departments in Dietrich College:

73-476	American Economic History	9
76-230	Literature & Culture in the 19th Century	9
76-239	Introduction to Film Studies	9
76-295	Russian Cinema: From the Bolshevik Revolution to Putin's Russia	9
80-135	Introduction to Political Philosophy	9
80-226	The Nature of Scientific Revolutions	9
80-335	Social and Political Philosophy	9
82-245	New Directions in Hispanic Studies	9
82-247	US Latinos Literature	9
82-293	Russian Cinema: From the Bolshevik Revolution to Putin's Russia	9
82-327	The Emergence of the German Speaking World	9
82-420	The Crucible of Modernity:Vienna 1900	9
82-427	Nazi and Resistance Culture	9
84-275	Comparative Politics	9
84-322	Nonviolent Conflict and Revolution	9
84-324	The Future of Democracy	9
84-325	Contemporary American Foreign Policy	9
84-362	Diplomacy and Statecraft	9
84-380	US Grand Strategy	9
84-386	The Privatization of Force	9
84-389	Terrorism and Insurgency	9
85-380	In Search of Mind: The History of Psychology	9
88-281	Topics in Law: 1st Amendment	9
88-284	Topics of Law: The Bill of Rights	9

VI. 79-505: SPH Internship (6-9 units)

The Social & Political History program strongly encourages students to locate internship opportunities in Pittsburgh or elsewhere that complement their historical interests (as, for example, in a museum or historical society) or in areas of policy research that complement their historical interests (as, for example, in a government agency or non-profit organization). The Academic Program Manager will assist students with matching their interests to local organizations. SPH students can earn up to 9 units in each internship. Please note, however, that internship credits do not count toward fulfillment of course requirements for the SPH major (though the units do count toward graduation).

VII. Additional Major in Social & Political History (*SPH*)

The Social & Political History Major may be scheduled as an additional major in consultation with the Academic Program Manager, Dr. Alexandra Garnhart-Bushakra, History Department, Baker Hall 240.

VIII. Bachelor of Science Option

Students may elect to earn a Bachelor of Science rather than a Bachelor of Arts degree by completing two courses from the list below, or by petitioning the Academic Program Manager, Dr. Alexandra Garnhart-Bushakra, History Department, Baker Hall 240, to accept equivalent courses as substitutions.

21-257	Models and Methods for Optimization	9
36-202	Methods for Statistics & Data Science	9
or 70-208	Regression Analysis	
36-303	Sampling, Survey and Society	9
36-309	Experimental Design for Behavioral & Social Sciences	9
70-257	Optimization for Business	9
80-305	Game Theory	9
80-306	Decision Theory	9
88-221	Markets, Democracy, and Public Policy	9
88-223	Decision Analysis	12
88-251	Empirical Research Methods	9
88-300	Programming and Data Analysis for Social Scientists	9

The Major in Global Studies

Professor Ricky Law, *Director of Undergraduate Studies and Director of Global Studies,* History Department
Location: Baker Hall 238B, 412-268-2880, rlaw@andrew.cmu.edu (egrama@andrew.cmu.edu)

Dr. Alexandra Garnhart-Bushakra, *Academic Program Manager*, History Department
Location: Baker Hall 240G, 412-268-1260, agarnhar@andrew.cmu.edu

www.cmu.edu/hss/globalstudies (https://www.cmu.edu/hss/globalstudies/)

The B.A. in Global Studies is an interdepartmental major designed for students interested in humanistic approaches to past and present processes of globalization. The rigorous yet flexible Global Studies curriculum combines courses in anthropology, history, cultural studies, and language training that enable students to gain a nuanced understanding of both global processes and regional histories and cultures. Graduates of the program have pursued careers in a wide range of fields, including law, the private and non-governmental sectors, and graduate work in psychology, business, health and medicine, and international studies.

Faculty affiliated with the program come from the departments of History, Languages, Cultures, and Applied Linguistics, English, and Philosophy, and draw on their international expertise to help students gain a rich, multidisciplinary understanding of global issues and concerns (such as, climate change and the environment; migration; social and political movements; imperial legacies and contemporary politics; art, language, culture, and globalization.)

Students should consult with the Global Studies Academic Program Manager about new courses and study abroad courses that may be approved for the Global Studies major.

Global Studies may be elected as a **primary** or an **additional** major; the requirements for each are the same.

Curriculum

(102 units plus completion of language requirement)

There are three required courses for the major: Introduction to Global Studies (79-275), Global Studies Research Seminar (79-400) and one of the following general education courses: Introduction to Anthropology (79-201, 9 units), Introduction to African American History: Black Americans and the World (79-120, 9 units), Genocide and Weapons of Mass Destruction (79-145, 9 units), Introduction to the History of Science (79-160, 9 units)), Democracy and History: Thinking Beyond the Self (79-189, 9 units), Technology and Society (79-234, 9 units), or How Do We Remember? The Politics and Cultures of Memory (79-314, 9 units). In addition to these three courses, majors must also complete 72 units of electives and demonstrate proficiency in a modern language other than English. Students may double count a maximum of four courses taken for the Global Studies major that are also being used to fulfill the requirements of other majors and programs. Students should consult with the Global Studies Academic Program Manager about new courses and study abroad courses that may be approved for students pursuing the major in Global Studies.

I. Required General Education Course (9 units)

79-201	Introduction to Anthropology	9
79-120	Introduction to African American History: Black Americans and the World	9
79-145	Genocide and Weapons of Mass Destruction	9
79-160	Introduction to the History of Science	9
79-189	Democracy and History: Thinking Beyond the Self	9
79-234	Technology and Society	9
79-314	How Do We Remember? The Politics and Cultures of Memory	9

II. Global Studies Introductory Course (9 units)

Students must earn a final grade of "C" or better for the course to count toward the major.

79-275	Introduction to Global Studies	9

III. Language Requirement

Demonstrating intermediate to advanced level proficiency in a language other than English is a crucial component of the major in Global Studies. Normally this requirement can be satisfied by successfully completing a course conducted in the second language at the 300 level or above for French, German, Italian, or Spanish, or the fourth semester (Intermediate II) level or above for Arabic, Chinese, Japanese, or Russian. Comparable proficiency for other languages can be considered. Additional advanced cultural, historical, and literary study in the second language is strongly recommended. Courses in a language other than English may also be counted as Global Studies transnational, global, or regional courses or Global Studies electives as appropriate.

Studying abroad for one semester, in a foreign country whose language is not English, is an alternative way to fulfill the language requirement.

Please see the Languages, Cultures, and Applied Linguistics section of the schedule of classes.

IV. Theoretical and Topical Core Courses (18 units)

To gain a solid foundation in the theories and analytical topics underpinning the B.A. in Global Studies, students select 18 units (typically two courses). Students must earn a final grade of "C" or better in these courses to fulfill the theoretical and topical core course requirement.

79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-278	How (Not) to Change the World	9
79-280	Coffee and Capitalism	9
79-289	Animal Planet: An Environmental History of People and Animals	9
79-314	How Do We Remember? The Politics and Cultures of Memory	9
79-315	The Politics of Water in Global Perspective	9
79-317	Art, Anthropology, and Empire	9
79-318	Sustainable Social Change: History and Practice	9
79-377	Food, Culture, and Power: A History of Eating	9
79-379	Extreme Ethnography	9
79-380	Hostile Environments: The Politics of Pollution in Global Perspective	9
79-383	The History of Capitalism	9

V. Transnational, Global, and Regional Courses (27 units)

To gain insight into how complex transnational and global processes shape and are affected by local, national, and regional dynamics, students will select 27 units (typically three courses).

Transnational and Global Courses

76-337	Intersectional Feminism	9
76-353	Transnational Feminisms: Fiction and Film	9
76-384	Race, Nation, and the Enemy	9
76-440	Postcolonial Theory: Diaspora and Transnationalism	9
79-149	Ancient Rome: What Have the Romans Ever Done for Us?	9
79-237	Comparative Slavery	9
79-273	Jews and Muslims in History	9

79-270	Anti-Semitism Then and Now: Perspectives from the Middle Ages to the Present	9
79-276	Beyond the Border	9
79-280	Coffee and Capitalism	9
79-282	Europe and the World Since 1800	9
79-283	Hungry World: Food and Famine in Global Perspective	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-313	"Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration	6
79-333	African Americans, Race, and the Fight for Reparations	9
79-350	Early Christianity	9
79-368	Un-natural Disasters: Societies and Environmental Hazards in Global Perspective	6
79-385	Out of Africa: The Making of the African Diaspora	9
79-510	Global Studies Guided Reading	3
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9
82-283	Language Diversity & Cultural Identity	9
82-304	French & Francophone Sociolinguistics	9
82-345	Using Spanish in Social Contexts	9
84-226	International Relations	9
84-322	Nonviolent Conflict and Revolution	9
84-370	Nuclear Security & Arms Control	9
84-389	Terrorism and Insurgency	9

Regional Courses

Africa:

79-225	West African History in Film	9
79-226	African History: Earliest Times to 1780	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-290	The Slave Passage: From West Africa to the Americas	9

Eastern and Southern Asia and the Pacific:

79-207	Asian American History through the Novel	9
79-210	Identity, Ethnicity, and Place in Modern China	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-264	Tibet and China: History and Propaganda	9
88-411	Rise of the Asian Economies	9

Europe:

79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-203	The Other Europe: The Habsburgs, Communism, & Central/Eastern Europe, 1740-1990	9
79-205	20th Century Europe	9
79-208	Witchcraft and Witch-Hunting	9
79-268	World War I: The Twentieth Century's First Catastrophe	9
79-270	Anti-Semitism Then and Now: Perspectives from the Middle Ages to the Present	9
79-272	Coexistence and Conflict: Muslims, Christians and Jews in Spain and Portugal	9
82-320	Contemporary Society in Germany, Austria and Switzerland	9
82-415	Topics in French and Francophone Studies	9
82-441	Studies in Peninsular Literature and Culture	9

The Middle East:

79-229	The Origins of the Palestinian-Israeli Conflict, 1880-1948	9
79-230	The Arab-Israeli Conflict and Peace Process Through 1948 to Present	9
82-215	Arab Culture Through Dialogues, Film, and Literature	9
84-323	War and Peace in the Contemporary Middle East	9

The Americas:

79-223	Mexico: From the Aztec Empire to the Drug War	9
82-245	New Directions in Hispanic Studies	9
82-343	Latin America Language and Culture	9
82-451	Studies in Latin American Literature and Culture	9
82-455	Topics in Hispanic Studies	9
82-456	Topics in Hispanic Studies	9

VI. Elective Courses (27 units)

Please schedule an appointment with the academic program manager for guidance in selecting appropriate Thematic and region-based courses that satisfy Global Studies degree requirements.

Students are required to take an additional 27 units of elective courses, selected from one or both of the subcategories below. Any History course (79-xxx) not listed above at the 200 level or higher will count as an elective. In addition, Category IV and V courses listed above that are not used to fulfill those requirements may be counted as electives in addition to the courses listed below.

Students should consult each semester with the Global Studies Academic Program Manager, Dr. Alexandra Garnhart-Bushakra, about new courses approved for the Global Studies major. Students may “double-count” a maximum of four courses for the Global Studies major that are used to fulfill the requirements of other majors and programs. (Note that some of the courses may have prerequisites established by the departments offering them. Students should consult with the academic advisor about how such prerequisites may affect their course of study.)

Please visit the Department of History’s Current Courses webpage to see what is available. You can also see a list of electives in the Undergraduate Course Catalog.

Thematic Elective Courses

57-306	World Music	9
70-365	International Trade and International Law	9
76-241	Introduction to Gender Studies	9
76-386	Language & Culture	9
76-450	Law, Culture, and the Humanities	9
76-468	Space and Mobilities	9
79-101	Making History: How to Think About the Past (and Present)	9
79-204	American Environmental History	9
79-281	Introduction to Religion	9
79-316	Photography, the First 100 Years, 1839-1939	9
79-324	#MeToo: Naming and Resisting Gender Violence	6
79-330	Medicine and Society: Health, Healers, and Hospitals	9
79-343	Education, Democracy, and Civil Rights	9
80-244	Environmental Ethics	9
80-335	Social and Political Philosophy	9
82-215	Arab Culture Through Dialogues, Film, and Literature	9
82-541	Special Topics in Hispanic Studies	Var.
84-275	Comparative Politics	9
84-310	Policy in a Global Economy 1: International Trade and Trade Policy	6
84-318	Politics of Developing Nations	9
84-362	Diplomacy and Statecraft	9
88-234	Negotiation: International Focus	9

Area–based Elective Courses

79-216	Genghis Khan and the Mongol Empire	3
79-256	Sex, Guns, Rock, and Skinheads: Youth Rebellion in Europe, 1960-1990	9
79-257	Germany and the Second World War	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-263	Mao and the Chinese Cultural Revolution	9
79-265	Russian History: Game of Thrones	9
79-266	Russian History and Revolutionary Socialism	9
79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-269	Russian History: From Socialism to Capitalism	9

79-309	The Chinese Revolution Through Film (1949-2000)	9
79-319	India Through Film	6
79-320	Women, Politics, and Protest	9
79-322	Stalin and the Great Terror	9
79-326	Shall We Dance? Culture, Politics, and Movement in the 20th Century	6
79-331	Body Politics: Women and Health in America	9
82-253	Korean Culture Through Film	9
82-254	World of Korea, Then and Now	9
82-273	Introduction to Japanese Language and Culture	9
82-278	Japanese Film and Literature: The Art of Storytelling	9
82-293	Russian Cinema: From the Bolshevik Revolution to Putin's Russia	9
82-294	19th Century Russian Masterpieces	Var.
82-295	20th Century Russian Masterpieces	Var.
82-303	French & Francophone Cultures	9
82-305	French in its Social Contexts	9
82-333	Introduction to Chinese Language and Culture	Var.
82-342	Spain: Language and Culture	9
82-344	U.S. Latine Cultures	9
82-361	Italian Language and Culture I	9
82-420	The Crucible of Modernity:Vienna 1900	9
82-425	Topics in German Literature and Culture	Var.
82-427	Nazi and Resistance Culture	9
82-428	History of German Film	9
82-433	Topics in Contemporary Culture of China	9
82-434	Studies in Chinese Traditions	9
82-440	Studies in Chinese Literature & Culture	9
82-473	Topics in Japanese Studies	9

VII. Senior Capstone Course (12 units)

The research seminar is the capstone course for Global Studies majors and is designed to give students the chance to define and carry out a research project of personal interest. Students are strongly encouraged to incorporate their prior coursework (including foreign language training), study abroad, or internships into their research. Students must earn a final grade of "C" or better for the course to count toward the major.

79-400	Global Studies Research Seminar	12

Global Studies Major — Sample Curriculum

This sample curriculum presents a course of study for completing the requirements for the Global Studies major that includes an optional study abroad semester. Students may declare the Global Studies major and take required courses as early as the second semester of the freshman year and as late as the junior year.

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
79-201 Introduction to Anthropology or 79-145, Genocide and Weapons of Mass Destruction or 79-189, Democracy and History: Thinking Beyond the Self	79-275 Introduction to Global Studies	GS Theoretical & Topical Core Course	GS Theoretical & Topical Core Course
First-Year Writing Requirement	Language Course or Gen Ed	GS Transnational, Global, Regional Course	GS Transnational, Global, Regional Course
Grand Challenge Seminar	36-200 Reasoning with Data	Language Course or Gen Ed	Language Course or Gen Ed
Language Course or Elective	Fourth Course (open)	General Education Course	General Education Course
Fifth Course (open)	Fifth Course (open)	Fifth Course (open)	Fifth Course (open)
99-101 Core@CMU			

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
GS Transnational, Global, Regional Course	STUDY ABROAD*	79-400 Global Studies Research Seminar	Language Course or Elective
GS Elective	GS Elective	Language Course or Elective	Elective**
Language Course or Gen Ed	GS Elective	Elective**	Third Course (open)
Fourth Course (open)	Language Course or Gen Ed	Fourth Course (open)	Fourth Course (open)
Fifth Course (open)	Fourth Course (open)	Fifth Course (open)	Fifth Course (open)
	Fifth Course (open)		

*Spring semester of the junior year is a popular semester for study abroad. However, Global Studies majors may instead choose to study abroad in spring of sophomore year, or fall of junior year. Students should discuss study abroad and curricular planning with the Academic Program Manager, Dr. Alexandra Garnhart-Bushakra, History Department, Baker Hall 240. Study Abroad in a summer program is also an option.

**Many Global Studies majors choose to apply for the senior honors thesis program. The department strongly encourages students to take advantage of this option.

VIII. Additional Major

Global Studies may be elected as a primary or an additional major; the requirements for each are the same. Contact the Academic Program Manager, Dr. Alexandra Garnhart-Bushakra, History Department, Baker Hall 240G, to elect the additional major.

The Major in Ethics, History, and Public Policy

Professor Steven Schlossman, Director of Ethics, History, and Public Policy, History Department
Location: Baker Hall 236A, 412-268-2880
sls@andrew.cmu.edu

Dr. Alexandra Garnhart-Bushakra, *Academic Program Manager*, History Department
Location: Baker Hall 240, 412-268-2880
agarnhar@andrew.cmu.edu
https://go.oncehub.com/AlexGarnhartBushakra (https://calendar.google.com/calendar/u/0/appointments/schedules/AcZssZ24Bwky_tkdT8oSWDK0w6cwg1GvEhFDegMNcZPEEmtJ8IILU5DHrd0EVab-VLXcmKjZUc8-JqI0/)

Patrick Doyle, *Academic Program Manager*, Philosophy Department
Location: Baker Hall 161G, 412-268-3704
pdoyle2@andrew.cmu.edu
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The B.A./B.S. in Ethics, History, and Public Policy (EHPP) is an interdepartmental major offered jointly by the Departments of History and Philosophy.

Preparing students to be leaders is a vital goal of colleges and universities in every democratic society. The intellectual challenges facing public and private sector leaders have expanded dramatically since the pioneering EHPP program began in 1996, but the need remains as great as ever for broadly educated, ethically sensitive, and technically skilled leaders.

EHPP prepares students to demonstrate sophistication and flexibility in their command of interdisciplinary knowledge; deep historical understanding of how modern-day policy problems have emerged and evolved; and clear, rational criteria for ethical and socially just decision making. The curriculum provides students with a strong humanistic foundation for developing such high-level, historically grounded, and ethically attuned leadership capacities. It also offers ample room for specialization in a wide range of policy areas in which the History and Philosophy departments have special expertise, e.g., medicine and public health, criminal justice, environment, technology, artificial intelligence (AI), gender, civil rights, immigration, and education.

Curriculum

Students seeking a primary major in Ethics, History, and Public Policy may elect to receive either a Bachelor of Arts or a Bachelor of Science degree (additional requirements apply; see below). Basic requirements include 120 units encompassing 45 units in History, 45 units in Philosophy, 18 units in Law and Social Science, and a 12-unit EHPP Capstone Course. This program may also be taken as an additional (i.e., second) major. All courses toward the major must be taken for a letter grade and must be passed with a grade of "C" or better. Students can double count any course for the major with another major or minor, with the exception of Social and Political History, for which a student can double count a maximum of two courses.

I. Foundation Courses in History and Philosophy **18 units**

Choose one of the following two courses:

79-189	Democracy and History: Thinking Beyond the Self	9
79-248	U.S. Constitution & the Presidency	9

Choose one of the following two courses:

80-130	Introduction to Ethics	9
80-330	Ethical Theory	9

II. Ethics and Policy Core 36 units

Choose four of the courses below:

No more than one course may be taken at the 100 level and at least one course must be taken at the 300 level or above.

80-135	Introduction to Political Philosophy	9
80-136	Social Structure, Public Policy & Ethics	9
80-208	Critical Thinking	9
80-221	Philosophy of Social Science	9
80-234	Race, Gender, and Justice	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-249	AI, Society, and Humanity	9
80-305	Game Theory	9
80-306	Decision Theory	9
80-324	Philosophy of Economics	9
80-330	Ethical Theory	9
80-335	Social and Political Philosophy	9
80-336	Philosophy of Law	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9

III. History and Policy Core 36 units

Choose four of the courses below:

79-175	Moneyball Nation: Data in American Life	9
79-204	American Environmental History	9
79-212	Jim Crow America	9
79-215	Environmental Justice from Conservation to Climate Change	9
79-234	Technology and Society	9
79-242	African American History: Reconstruction to the Present	9
79-248	U.S. Constitution & the Presidency	9
79-250	Voting Rights: An Introduction	9
79-278	How (Not) to Change the World	9
79-300	Controversial Topics in the History of American Public Policy	9
79-320	Women, Politics, and Protest	9
79-321	Documenting Human Rights	9
79-330	Medicine and Society: Health, Healers, and Hospitals	9
79-343	Education, Democracy, and Civil Rights	9
79-360	Crime, Policing, and the Law: Historical and Contemporary Perspectives	9
79-370	Technology in the United States	9
79-380	Hostile Environments: The Politics of Pollution in Global Perspective	9

IV. Foundation Courses in Law and Social Science 18 units

Choose two of the courses below:

17-200	Ethics and Policy Issues in Computing	9
19-101	Introduction to Engineering and Public Policy	12
70-332	Business, Society and Ethics	9
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
84-104	Decision Processes in American Political Institutions	9
84-110	The Economics of Politics, Policy, and Technology	9
84-352	Representation and Voting Rights	9
84-393	Legislative Decision Making: US Congress	9
84-402	Judicial Politics and Behavior	9
88-281	Topics in Law: 1st Amendment	9
88-284	Topics of Law: The Bill of Rights	9

EHPP students will also be able to complete the Foundations of Law and Social Science category by participating in the Washington Semester Program. Students are encouraged to pursue additional policy-relevant courses in law and social science, along lines consistent with their career ambitions.

V. EHPP Capstone Course 12 units

In Fall semester of senior year, EHPP students will participate in an interdisciplinary capstone course that asks students to integrate their studies in Ethics and History by addressing a policy topic of contemporary national urgency (e.g., climate change, immigration, infrastructure, abortion, hate speech, reparations, law enforcement and policing, charter schools, affirmative action, vaccination, taxation, voting rights, global justice). The Departments of History and Philosophy will alternate teaching the EHPP Capstone Course.

79-449	EHPP Capstone Course [cross-listed]	12
80-449	EHPP Capstone Course [cross-listed]	12

VI. Bachelor of Science Option

Students may elect to earn a Bachelor of Science rather than a Bachelor of Arts degree by completing two courses from the list below, or by petitioning the Director of EHPP to accept equivalent courses as substitutions.

21-257	Models and Methods for Optimization	9
36-202	Methods for Statistics & Data Science	9
or 70-208	Regression Analysis	
36-303	Sampling, Survey and Society	9
36-309	Experimental Design for Behavioral & Social Sciences	9
70-257	Optimization for Business	9
80-305	Game Theory	9
80-306	Decision Theory	9
88-221	Markets, Democracy, and Public Policy	9
88-223	Decision Analysis	12
88-251	Empirical Research Methods	9
88-300	Programming and Data Analysis for Social Scientists	9

Additional Major

The B.A./B.S. in Ethics, History, and Public Policy may be scheduled as an additional major in consultation with the Director of Ethics, History, and Public Policy.

Ethics, History, and Public Policy Sample Curriculum

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
Foundations Course in History	Foundations Course in Law and Social Sciences	EHPP Capstone Course	Ethics and Policy Core Course
Foundations Course in Philosophy	Foundations Course in Law and Social Sciences	Ethics and Policy Core Course	History and Policy Core Course
Ethics and Policy Core Course	Ethics and Policy Core Course	History and Policy Core Course	Third Course (open)
History and Policy Core Course	History and Policy Core Course	Fourth Course (open)	Fourth Course (open)
Fifth Course Open	Fifth Course (open)	Fifth Course (open)	Fifth Course (open)

The above sample program is presented as a two-year (junior-senior year) plan for completing EHPP major requirements. Its purpose is to show that this program can be completed in as few as two years; not that it must be.

Students may enter the EHPP major, and begin major course requirements, as early as they wish. Students should consult their advisor when planning their program.

The Minor in Social & Political History (*SPH*)

Professor Ricky Law, *Director of Undergraduate Studies,* History Department

Location: Baker Hall 238B, 412-268-2880, rlaw@andrew.cmu.edu

Dr. Alexandra Garnhart-Bushakra, *Academic Program Manager*, History Department
Location: Baker Hall 240G, 412-268-1260, agarnhar@andrew.cmu.edu

www.cmu.edu/dietrich/history/undergraduate/minors/sph.html (https://www.cmu.edu/dietrich/history/undergraduate/minors/sph.html)

The minor in Social & Political History involves a minimum of 54 units of History course work.

Curriculum (54 units)

I. Required History Survey Courses (choose two -- 18 units)

Students must complete 18 units (typically 2 courses) from the following list of survey courses:

79-120	Introduction to African American History: Black Americans and the World	9
79-160	Introduction to the History of Science	9
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-203	The Other Europe: The Habsburgs, Communism, & Central/Eastern Europe, 1740-1990	9
79-204	American Environmental History	9
79-205	20th Century Europe	9
79-206	Crime and Punishment in Early Modern Europe	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-212	Jim Crow America	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-225	West African History in Film	9
79-226	African History: Earliest Times to 1780	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-229	The Origins of the Palestinian-Israeli Conflict, 1880-1948	9
79-230	The Arab-Israeli Conflict and Peace Process Through 1948 to Present	9
79-240	Development of American Culture	9
79-242	African American History: Reconstruction to the Present	9
79-244	Women in American History	9
79-245	Capitalism and Individualism in American Culture	9
79-248	U.S. Constitution & the Presidency	9
79-249	20th Century U.S. History	9
79-250	Voting Rights: An Introduction	9
79-255	Modern Ireland: Politics and Culture from the Famine (1847) to Today	9
79-260	Nazi Germany	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-265	Russian History: Game of Thrones	9
79-266	Russian History and Revolutionary Socialism	9
79-269	Russian History: From Socialism to Capitalism	9
79-272	Coexistence and Conflict: Muslims, Christians and Jews in Spain and Portugal	9
79-282	Europe and the World Since 1800	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-320	Women, Politics, and Protest	9

II. Elective courses for the Minor in Social & Political History (36 units)

Students must complete 36 elective History units (typically 4 courses). Social & Political History minors have considerable flexibility in choosing their elective courses, but should feel free to consult with the Director of Undergraduate Studies in making their selections.

The Minor in Anthropology

Professor Noah Theriault, *Faculty Advisor,* History Department
Location: Baker Hall 240C, noaht@andrew.cmu.edu

Dr. Alexandra Garnhart-Bushakra, *Academic Program Manager*, History Department
Location: Baker Hall 240G, 412-268-1260, agarnhar@andrew.cmu.edu

www.cmu.edu/dietrich/history/undergraduate/minors/anthropology.html (https://www.cmu.edu/dietrich/history/undergraduate/minors/anthropology.html)

The Minor in Anthropology exposes students to the methods and theories that anthropologists use to study cultural variation and change. Courses in the minor explore the history and practice of ethnography, apply anthropological approaches to global problems, and examine how cultural differences interact with a range of other social, political, and environmental forces. Students also gain a deeper understanding of how cultural differences shape (and are shaped by) the arts, technology, economics, politics, and ecology. The minor, which may be combined with any major, equips students with a sophisticated understanding of human diversity in a rapidly changing world.

The Minor in Anthropology requires that students complete two "Methods" courses (18 units) and four "Anthropological Perspectives" courses (36 units). In addition, 79-201 Introduction to Anthropology is required (9 units), but it may be taken at any time during the student's coursework. Including this course, the Minor in Anthropology totals 63 units.

Curriculum (63 units)

I. General Education Course, Disciplinary Perspectives: Social Sciences (9 units)

This requirement need not be satisfied before beginning the minor.

79-201	Introduction to Anthropology	9

II. Methods (18 units)

Students must complete 18 units (typically 2 courses) in Methods, selecting from the list below. (Other courses may fulfill these requirements, with permission of the Faculty Advisor.)

79-275	Introduction to Global Studies	9
79-314	How Do We Remember? The Politics and Cultures of Memory	9
79-317	Art, Anthropology, and Empire	9
79-379	Extreme Ethnography	9
79-380	Hostile Environments: The Politics of Pollution in Global Perspective	9

III. Anthropological Perspectives (36 units)

Students must complete 36 units (typically 4 courses) in Anthropological Perspectives, selecting from the list below. (Other courses may fulfill these requirements, with permission of the Faculty Advisor.)

57-306	World Music	9
79-170	Introduction to Science, Technology, and Society	9
79-203	The Other Europe: The Habsburgs, Communism, & Central/Eastern Europe, 1740-1990	9
79-208	Witchcraft and Witch-Hunting	9
79-210	Identity, Ethnicity, and Place in Modern China	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-215	Environmental Justice from Conservation to Climate Change	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-234	Technology and Society	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-264	Tibet and China: History and Propaganda	9
79-275	Introduction to Global Studies	9
79-276	Beyond the Border	9

79-278	How (Not) to Change the World	9
79-280	Coffee and Capitalism	9
79-313	"Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration	6
79-314	How Do We Remember? The Politics and Cultures of Memory	9
79-315	The Politics of Water in Global Perspective	9
79-317	Art, Anthropology, and Empire	9
79-368	Un-natural Disasters: Societies and Environmental Hazards in Global Perspective	6
79-331	Body Politics: Women and Health in America	9
79-371	African American Urban History	9
79-377	Food, Culture, and Power: A History of Eating	9
79-379	Extreme Ethnography	9
79-380	Hostile Environments: The Politics of Pollution in Global Perspective	9

Relevant Anthropology courses may be taken at another university (for instance, study abroad, the University of Pittsburgh, or other Pittsburgh institutions) with permission of the Anthropology Minor's Faculty Advisor.

Senior Honors

Senior Honors Thesis: Dietrich College

The Dietrich College Honors Program may be undertaken by students completing the major in Social & Political History, the major in Global Studies, or the interdepartmental major in Ethics, History, and Public Policy. An Honors Thesis requires two semesters of work. Eligibility requirements are set by the College; contact the Associate Dean of Dietrich College for details.

Study Abroad

Study abroad is especially encouraged for all students in the History Department; this experience can help students better understand the relationship between cultural heritage and modern political processes in a host country. To make study abroad successful and determine how specific study abroad programs fit into History Department graduation requirements, History majors should consult with a relevant faculty member and/or with the Academic Advisor.

Faculty

JAY D. ARONSON, Professor of History – Ph.D., University of Minnesota; Carnegie Mellon, 2004–

ALLYSON F. CREASMAN, Associate Professor of History; Interim Head – Ph.D., University of Virginia; Carnegie Mellon, 2005–

ERIN DEAN, Associate Professor of Anthropology and History – Ph.D., University of Arizona; Carnegie Mellon, 2024–

PAUL K. EISS, Associate Professor of Anthropology and History – Ph.D., University of Michigan; Carnegie Mellon, 2000–

EDDA L. FIELDS-BLACK, Professor of History – Ph.D., University of Pennsylvania; Carnegie Mellon, 2001–

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DEEPA NAIR, Assistant Teaching Professor of History, Carnegie Mellon-Qatar – Ph.D., National University of Singapore; Carnegie Mellon, 2019–

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Affiliated Faculty

AIDAN BEATTY, Graduate Academic Advisor and Lecturer – Ph.D., University of Chicago; Carnegie Mellon, 2023–

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JOSEPH E. DEVINE, Associate Dean for Undergraduate Studies, Dietrich College of Humanities and Social Sciences – D.A., Carnegie Mellon University; Carnegie Mellon, 1979–

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JASON HOSTUTLER, Humanities Advisor, Dietrich College of Humanities and Social Sciences – Ph.D., University of Wisconsin–Madison; Carnegie Mellon, 2023–

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CHRISTOPHER WARREN, Professor of English and Associate Department Head with a Courtesy Appointment in History – D. Phil., University of Oxford;

Emeriti

CAROLINE JEAN ACKER, Associate Professor Emeritus of History – Ph.D., University of California, San Francisco; Carnegie Mellon, 1993–

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DONNA HARSCH, Professor Emeritus of History – Ph.D., Yale University; Carnegie Mellon, 1990–

KATHERINE A. LYNCH, Professor Emeritus of History – Ph.D., Harvard University; Carnegie Mellon, 1980–

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JOHN MODELL, Professor Emeritus of History – Ph.D., Columbia University; Carnegie Mellon, 1982–

DANIEL P. RESNICK, Professor Emeritus of History – Ph.D., Harvard University; Carnegie Mellon, 1966–

JUDITH SCHACHTER, Professor Emeritus of Anthropology and History – Ph.D., University of Minnesota; Carnegie Mellon, 1984–

DONALD S. SUTTON, Professor Emeritus of History and Anthropology – Ph.D., Cambridge University, England; Carnegie Mellon, 1969–

JOEL A. TARR, Richard S. Caliguiri University Professor of History and Policy – Ph.D., Northwestern University; Carnegie Mellon, 1967–

Department of History Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

79-101 Making History: How to Think About the Past (and Present)

Intermittent: 9 units
Who makes history? This apparently straightforward question is at the heart of studying the past, but it is also an important question to answer if we are to understand the world around us. Being able to answer the question "Who and what caused changes to political, cultural, economic, and environmental systems?" is fundamental to thinking about the past, but it is also essential to analyzing current issues as widespread and yet connected as economic inequality, social justice, and climate change. "Making History" is an introductory course ideal for students who are curious about the past and want to learn how to become better critical thinkers by applying its lessons to the present. The course explores how history is made on two levels: both the historical events themselves and how those events are documented, interpreted, and remembered. In other words, making history is not just about understanding what happened, but what it meant to different groups of people then and what it means to different groups of people now. We'll visit some famous (and not-so-famous) historical events and actors to learn about how individual choices combine with deeper structural factors, like gender, race, environment, and class to "make history." Along the way, we'll also encounter different ways to interpret the past, drawing upon the latest scholarship to understand how historians think about the past and #8212; and present. Students will be encouraged to synthesize what they learn in class to develop their own critical perspectives on their lives and the world around them. This course fulfills Dietrich College's "Humanities" general education requirement.

79-104 Global Histories

Fall and Spring: 9 units
Human activity transcends political, geographical, and cultural boundaries. From wars to social movements, technological innovations to environmental changes, our world has long been an interconnected one. Acquiring the ability to understand such transnational and even worldwide processes is an indispensable part of any college education. This course provides students with an opportunity to develop the skills and perspectives needed to understand the contemporary world through investigating its global history. All sections are comparable in their composition of lectures and recitations, required amounts of reading, and emphasis on written assignments as the central medium of assessment. The sections all aim to help students: (1) master knowledge through interaction with the instructors, reading material, and other students, (2) think critically about the context and purpose of any given information, (3) craft effective verbal and written arguments by combining evidence, logic, and creativity, and (4) appreciate the relevance of the past in the present and future.

79-112 Introduction to Asian American History

Intermittent: 9 units
This introductory course surveys the histories of Asian Americans from the early nineteenth century to the present. We will cover major themes such as migration and diaspora, race, labor, citizenship, and identity and community formation as we examine the continuities and discontinuities between the Asian American past and present. Special attention will also be paid to both local and global aspects of Asian American history (in the United States, in other countries of the Americas, and in Asia) as we work to build a more robust understanding of what it means to be "Asian American" and how such social categorizations fit into broader patterns of construction and re-articulation according to varying historical contexts. This course fulfills Dietrich College's "Humanities" general education requirement.

79-120 Introduction to African American History: Black Americans and the World

All Semesters: 9 units
Exploring the history of Black Americans requires a global perspective. Beginning with early modern African civilizations, the transatlantic slave trade, the global age of revolutions, the implementation of transnational regimes of racial segregation, to the growth of transnational movements for civil and human rights, this course surveys the history of Black Americans from a global perspective. It analyzes how Black Americans conceived of their social position in relation to others in the world. It also explores how perspectives from across the world made sense of Black Americans. This course will follow African-descended people as they theorized, moved, migrated, and traveled throughout the world. From this perspective, students will learn about the diasporic dimensions of Black American identity. Students will also trace the historical circulation of African-descended people, knowledge, culture, and technologies. Students will analyze the important themes of freedom, movement, and migration from a global perspective. Through this course, students will learn that Black American historical actors have and continue to understand their position not only within the domestic social and political spheres of the United States but also in the global order of states and societies. From their marginalized social position, Black Americans, therefore, have articulated alternative frameworks for understanding the United States, the West, and the world. This is an introductory survey course. This course fulfills Dietrich College's "Intercultural and Global Inquiry" general education requirement.

79-145 Genocide and Weapons of Mass Destruction

Fall and Spring: 9 units
"Genocide" and "weapons of mass destruction" have been getting a lot of exposure lately - in the news, in popular culture, and even on the Fence on campus. What do they mean? Why was it necessary to invent them? How do we know when we are being confronted with them? What should we do then? This course surveys the history of genocide, weapons of mass destruction, and related phenomena. Can you imagine being responsible for the deaths of hundreds, thousands, or even millions of people? No? Almost everyone who ended up committing unspeakable atrocities had not been able to either. In fact, many of them still would not face their responsibility even after their complicity has been proven beyond doubt. Some convinced themselves, often sincerely, that there was no choice or that someone else was actually responsible. Others found reasons to justify, in their minds at least, taking many lives. Still others managed to forget that they had blood on their hands. How could anyone do such terrible things? More important, can you be sure that you would not act like them under similar circumstances? This course will teach you to look out for factors that turn ordinary people into mass killers. You will explore why conflicts break out and potential solutions. You will also learn to see from multiple perspectives and to be humble before history. Our exploration will begin with the European encounter with the Western Hemisphere and continue to 19th-century imperialism, the Holocaust, the atomic bombings of Japan, the Cold War, and decolonization and independence. By the end, you will have grasped the historical facts and contemporary concepts of genocide and weapons of mass destruction. You will also come to appreciate the significance of unintended consequences and the ambiguity of human progress, a realization that will guide you in life. This course meets the Dietrich Gen Ed "Intercultural and Global Inquiry" requirement.

79-149 Ancient Rome: What Have the Romans Ever Done for Us?

Intermittent: 9 units
The Romans are nowhere and everywhere in our world. Hundreds of years after anyone could plausibly claim to be Roman, the influence of ancient Rome is still palpable in our political institutions, religions, languages, geography, art, law, architecture, technology, and so much more. And not just in Europe. The legacy of ancient Rome can be felt in the Americas and elsewhere in the world. It affects how we think about the tension between West and East, the definitions of civilization and barbarism, and citizenship and belongingness in a multiethnic society. How did ancient Rome rise and how did it fall? Did it fall at all? How can a people who flourished about two thousand years ago still play a role now? If ancient Rome's impact is still so broad and deep, what lessons can or should we draw from the Romans? This course will explore these questions by tracing the history of Rome from its mythical and actual foundations to its expansion, gradual decline, and repeated renewals. At the end of the course, students will be able to answer that memorable question in Monty Python's Life of Brian: What have the Romans ever done for us?

79-160 Introduction to the History of Science

All Semesters: 9 units
This course provides an introduction to the history of modern science in Europe and North America, from the Enlightenment to the mid-twentieth century. Our goal is to understand scientific theories and practices on their own terms and as products of their own contexts, rather than as a progression of developments moving inevitably toward the present. The course seeks to explore both how and why science has become the dominant way of knowing about the natural world, as well as how scientific activity intersects with the history of religion, war, commerce, and the state. The course also introduces students to the history of science as a standalone discipline, and in particular to the similarities and differences with other objects of historical inquiry (art, politics, etc.). This course fulfills Dietrich College's "Humanities" general education requirement.

79-170 Introduction to Science, Technology, and Society

Intermittent: 9 units
Science and technology are among the most powerful transformative forces in today's global society. They shape the way we think about ourselves, the world around us, and even what is possible in the future. This course provides an introduction to Science and Technology Studies, a vibrant interdisciplinary field that examines the ways that science and technology interact with contemporary politics, culture, and society. Using theories and methods from history, philosophy, anthropology, sociology, and public policy, we will examine: the nature of scientific and technical knowledge; how facts are produced both inside and outside the laboratory; how politics and societal values impact scientific inquiry and the development of new technologies; whether objectivity is possible; what expertise is and the role that experts play in the world today; how our understanding of science and technology has been enhanced by focusing on issues of race, sex, gender, sexuality, and class; as well as the imperative to make science and technology more equitable and just than they have been in the past. Specific topics covered will include the development of military technologies like radar and the atomic bomb, genetic engineering and cloning, artificial intelligence, social media, transportation infrastructure, racial classification, gender identity, and the Covid-19 pandemic, among others. This course is meant to serve as a foundation for the new Science, Technology, and Society major, but it is open to anyone concerned with the social and political dimensions of science and technology.

79-175 Moneyball Nation: Data in American Life

Intermittent: 9 units
From conducting clinical trials and evaluating prisoners' parole cases to drafting professional ballplayers, we increasingly make decisions using mathematical concepts and models. This course surveys the development of and #8212;and resistance to and #8212;such tools by grounding them in the recent cultural history of the United States. Focusing on baseball, medicine, and the law, we'll explore how and why Americans have come to believe mathematical and computational methods can solve complicated problems, even in seemingly unrelated moral, political, and social domains. The course encourages students to think critically about the wider implications of these transformations by situating their development historically. This course fulfills Dietrich College's "Logic/Mathematical Reasoning" general education requirement.

79-189 Democracy and History: Thinking Beyond the Self

Fall and Spring: 9 units
Voters face a momentous decision. A fascist demagogue is running for president. He has already tried to seize power through an insurrection. It failed, but he mostly escaped punishment thanks to sympathetic or feckless judges. He mixes braggadocio, lies, flattery, empty promises, and a victimhood narrative to depict himself as the country's savior and to attract millions to his personality cult. If elected, he vows to make future elections unnecessary, rule as a dictator, stop outsiders from poisoning the nation's blood, and rid the country of leftist vermin. He fearmongers about who deserves membership in the nation, the country's international obligations, crime, the economy, and a faraway war to divide the people. The last person standing between him and his goal is an octogenarian president running for reelection. How will the voters decide? In addition to experiencing what happens to this country, we will examine democracy in ancient Rome, France, Japan, China, and Iran. Living in a democracy means thinking beyond the self and from others' perspectives. It means looking for facts but being open to different interpretations. And it means taking responsibility to think critically. These traits are also essential for understanding history. This course will train you in the historian's skillset and mindset so you can act democratically. You will learn to tell facts from opinions and to see from various angles. The course will push you to think for yourself and to argue effectively for your own position. These skills of thinking historically are useful not just for school or work, but they are indispensable to a democratic society. Democracy is chosen as the course theme because it is a feature that sets humans apart from other organisms. Knowing the history of democracy is knowing what it means to be human, which is the soul of the humanities. This course meets the Dietrich Gen Ed "Humanities" requirement.

79-198 Research Training: History

Fall and Spring: 9 units
This course is part of a set of 100-level courses offered by Dietrich College departments as independent studies for second-semester freshmen and first- or second-semester sophomores in the College. In general, these courses are designed to give students some real research experience through work on a faculty project in ways that might stimulate and nurture subsequent interest in research participation. Faculty and students devise a personal and regularized meeting and task schedule. Each Research Training course is worth 9 units, which generally means a minimum for students of about 9 work-hours per week. Prerequisites/restrictions: For Dietrich College students only; minimum cumulative QPA of 3.0 (at the time of registration) required for approved entry; additional prerequisites (e.g., language proficiency) may arise out of the particular demands of the research project in question. By permission of the relevant professor and the Director of Undergraduate Studies. Students sign up for these courses through both the History Department and the Dean's Office. Section A: The Right to Vote: An Unexpected History, L. Tetrault Section B: The History of Biostatistics, C. Phillips Section C: From "Banana Republic" to "Cup of Excellence:" Explaining the rise of Honduras in the Global Coffee Business, J. Soluri Section D: Mapping Segregated Medicine, E. Sanford

Course Website: https://www.cmu.edu/dietrich/students/undergraduate/programs/research-training-program.html

79-200 Introduction to Historical Research & Writing

Fall and Spring: 9 units
Introduction to Historical Research acquaints students with how historians practice their craft in interpreting events from the past. As a class, we will work together through a variety of tools in the historian's toolbox, using episodes from American history as case studies. By the second half of the semester, students will have identified their own topics, in any time period or field of history, and will write research papers incorporating the analytical techniques covered earlier. The goal is for students to learn the skills required to identify a research topic, find and work with many kinds of sources, create a strong thesis statement, design a persuasive paper, and produce a properly formatted and well written research paper.

79-201 Introduction to Anthropology

Intermittent: 9 units
Anthropologist Ruth Benedict claimed that anthropology's mission is truly to "make the world safe for human difference." Cultural anthropologists "make the strange familiar and the familiar strange," attempting to understand the internal logic of cultures which might, at first glance, seem bizarre to us. At the same time, anthropologists probe those aspects of our own society which might appear equally bizarre to outsiders. The goal of this course is to raise questions basic to the study of culture and social relationships in a multitude of contexts. We will also discuss the particular research methods informing anthropology, as well as anthropologists' relationship to the people they study, and the responsibilities informing those relationships. The readings focus on topics that have long captured anthropologists' attention and that continue to be intensely debated: social inequality, race, colonialism, body, kinship, religion, gender, social lives of things, globalization and migration. Through written work, including ethnographic readings and a novel, films, and in-class discussions, we will examine how anthropology makes us more aware of our own culturally ingrained assumptions, while broadening our understanding of human experiences. This course is structured as a combination of lectures and seminar discussions. In the first part of the course, I will give a lecture every week, followed by a class session that will focus solely on discussing the readings and key concepts. In the second part of the course, I will introduce the readings by placing them within larger debates, but the course will become more discussion oriented. This course fulfills Dietrich College's "Social Sciences" general education requirement. This class also satisfies one of the core requirements for the Anthropology minor.

79-202 Flesh and Spirit: Early Modern Europe, 1400-1750

Intermittent: 9 units
This course examines European history from the Black Death to the French Revolution, a period known to history as the "early modern" period. That is, it marks a period in European history that was not quite medieval, and yet not quite modern. Many features of modern society, such as the nation-state, free-trade economies, religious pluralism, scientific rationalism, and secular culture trace their origins to the early modern era, yet the period was also marked by important continuities with the Middle Ages. During this course, we will explore how Europeans re-imagined their world in its transition from the medieval to the modern. Topics to be considered will include the "renaissance" of the arts, the problems of religious reform, exploration and colonialism, the rise of science, and the expansion of the state. Through these developments, we will focus on Europeans' changing notions of the human body, the body politic, and the natural world, as well as their re-interpretations of the proper relation between the human and the divine, the individual and the community, and the present and the past.

79-203 The Other Europe: The Habsburgs, Communism, & Central/ Eastern Europe, 1740-1990

Intermittent: 9 units
During the last two centuries, Central and Eastern Europe has been a political laboratory and #8212;a region in which various political actors had attempted to launch and develop radical political and social experiments, from imperial reforms meant to strengthen and modernize the Habsburg empire, to the ethnic cleansing promoted by Nazi Germany and their acolytes in the region, to the attempts at establishing of a new social order under the post-WWII communist regimes. An understanding of the profound and rapid political and social changes that have occurred in this region will enable you to see global politics in a new light, and better understand the modern era. This course is a survey of the history of modern Central and Eastern Europe, from late 18th to late 20th century. It begins with a focus on modern Habsburg empire, the rise of nationalism in mid 19th century, and the demise of the Austro-Hungarian empire following the First World War. It continues with an examination of the rise of illiberal politics during the interwar era, the Second World War, and the establishment of the communist regimes and the Soviet sphere of influence during the Cold War. Course materials include secondary historical analyses, primary sources, memoirs, and documentaries. The course will rely heavily on the format of interactive lectures, a combination of lecture and discussion, which will productively challenge the students to engage with the material in a critical manner, and will help them contextualize and enrich the knowledge they gain from the course readings. This course fulfills Dietrich College's "Humanities" general education requirement.

79-204 American Environmental History

Intermittent: 9 units
This course examines how people in North America have interacted with their surroundings from the end of the last ice age to the present. This course fulfills Dietrich College's "Contextual Thinking" general education requirement.

79-205 20th Century Europe

Intermittent: 9 units
This course surveys the history of Europe from 1900 through the present. We shall examine some of the major political trends and social/economic changes of the last century, including: the collapse of Europe's multiethnic empires and the rise of the modern nation-state; the extraordinary violence and impact of WWI and the rise of ethno-nationalism and fascism during the inter-war period; The Spanish Civil War, WWII and the War in the Balkans in the 1990s. We will also examine Communism and its collapse; colonial resistance and the process of decolonization; and the creation of the European Union. In addressing contemporary Europe, we shall discuss: the re-emergence of ethno-nationalism and rising anti-immigrant sentiment and antisemitism over the last decades; cultural and political debates surrounding Islam and Muslims; contemporary debates over the memory of the Holocaust, and Russia's brutal war against Ukraine. Primary sources, academic articles, memoir and film will be used in the classroom to explore these topics. Classes will combine lecture, discussion and group work.

79-206 Crime and Punishment in Early Modern Europe

Intermittent: 9 units
This course will examine European legal and social institutions and their role in defining and punishing crime in the early modern era (c. 1400-1800). European society was fundamentally transformed in this period of transition between the medieval and the modern eras, and the laws and legal systems that exist in the Western world today reflect those influences at the deepest levels. This course will focus on how shifting definitions of "crime" and "punishment" reflected prevailing societal attitudes and anxieties toward perceived acts of deviance and persons on the margins of society. Assigned readings will examine the evolution of early modern European criminal court systems and the investigation and punishment of crime, focusing in particular on the historical debates concerning the use of torture and capital punishment and the evolution of modern policing and prisons. It will also address the criminalization of social deviance (witches, religious minorities, and other outcasts) and the legal enforcement of sexual norms and gender roles. The course concludes with an examination of current debates concerning criminal justice reform, policing, torture, and criminal punishment.

79-207 Asian American History through the Novel

Intermittent: 9 units
This course examines the interwoven histories of migration, language, and identity formation and re-formation in Asian American experience. How have migrant and diasporic identities been represented in fictional (or quasi-fictional) terms? How have factors such as race, religion, class, gender, and sexuality shaped everyday Asian American life? And how can literary sources enrich our understanding of such historical experiences? Course readings consist primarily of novels, representing a variety of Asian ethnicities and experiences, by authors including Gaiutra Bahadur, Carlos Bulosan, Maxine Hong Kingston, Joy Kogawa, Chang-Rae Lee, and John Okada. These works are supplemented by selected historical documents and short lectures to shed additional light onto the sociohistorical contexts and issues under study.

79-208 Witchcraft and Witch-Hunting

Intermittent: 9 units
Between the late 15th and the early 18th centuries, many Europeans became convinced that their society was threatened by a conspiracy of diabolic witches. Although Western beliefs in witchcraft and "devil worship" dated back to antiquity, the 16th and 17th centuries witnessed the most intense campaign of witch-hunting in all of Europe's history. Before it was over, the "Great European Witch-Hunt" of the early modern era cost the lives of thousands across Europe and in its colonies. And although the witch-hunts in early modern Europe and its colonies gradually came to an end, beliefs in witchcraft persist into the modern era and, in many parts of the world today, continue to generate campaigns of popular violence against alleged perpetrators. This course examines witchcraft beliefs and witch-hunting in historical perspective in both their European and colonial contexts. In addition to the early modern witch-hunts, it will address modern witchcraft beliefs and consider witch-hunting as a global problem today. It will focus on the origin and rationale of witch beliefs, the factors driving the timing and intensity of witch-hunts, and the patterns of accusations. Throughout, we will examine the many historical and regional variations in witch beliefs and prosecutions and explore how they reflect major social and cultural issues such as the relationship between "popular" and "elite" culture; religious change; state formation; gender and patriarchy; and the rationalization of law, medicine, and science. This course satisfies one of the elective requirements for the Religious Studies minor.

79-210 Identity, Ethnicity, and Place in Modern China

Intermittent: 9 units
Within popular imagination, China is often considered to be the world's oldest nation. As a result, concepts such as "China" and "Chinese" have become so embedded in our consciousness that we often fail to consider how, like all identities, ideas of Chinese-ness have been constructed hand-in-hand with the invention of the modern Chinese nation-state. This course examines nation-making in China from the outside in. We privilege avenues of inquiry that challenge state-sponsored narratives, complicate the hegemonic notion of "Han" as a majority identity, and consider ways in which processes of state consolidation and majoritization have subjected various ethnic, subethnic, diasporic, linguistic, gender, and religious communities to discrimination, marginalization, exclusion, and in some cases state and majoritarian violence. Rather than uncritically accepting the notion that China is a uniquely "historical nation," we instead consider the possibility that the Chinese state and nation are products of the same transglobal currentssuch as imperialism, settler colonialism, assimilation, minoritization, and exclusion that has made our modern world. Whenever possible, we employ historical texts, short stories, novels, memoirs, and film produced by members of disadvantaged, marginalized, and/or targeted communities in order to demonstrate how and why historical experiences and memories for example among "ethnic minorities" differ from the Han majority and from state orthodoxy, and why these differing perspectives matter. This course fulfills Dietrich College's "Perspectives on Justice and Injustice" general education requirement.

79-211 Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange

Intermittent: 9 units
When you hear the term "Southeast Asia," what comes to mind? The US War in Vietnam? The ruins of the Angkor civilization? Rich culinary traditions? Or perhaps your own heritage? However you imagine it, Southeast Asia is an incredibly diverse and dynamic region that has long been integral to world affairs and whose importance continues to grow. This course offers a wide-ranging survey of Southeast Asia's peoples, their histories, and some of the issues they face today. Together we will explore the region as a "global crossroads," where the world's religions, economies, cultures, and politics come together in generative, sometimes traumatic, and often surprising ways. This course fulfills Dietrich College's "Contextual Thinking" general education requirement.

79-212 Jim Crow America

Intermittent: 9 units
Michelle Alexander's The New Jim Crow (The New Pres 2010) has drawn attention to the ways that American institutions and social systems continue to produce racial inequalities. The recent failure of federal voting rights bills in the United States Congress and the proliferation of state-led efforts to constrain voting rights have led activists to claim "Jim Crow 2.0." Using these present-day assessments as a point of departure, this course introduces students to the Jim Crow period of American history spanning the late nineteenth century to the mid-twentieth century. From the 1890s to the 1950s, Black freedoms were limited by the policies and practices of racial segregation in the Jim Crow system of American apartheid. This course critically examines Black life in Jim Crow America, from the halls of federal power, to the every-day practices of racial subjugation and resistance. It examines cross-cutting themes: how racial segregation structured the legal, social, economic, and political sectors of American life; the role of national, state, and local policy mandating racial segregation; African American modes of resistance;vigilante and state racial violence. This course will also endeavor to make connections between the consequences of anti-Black racism and the social life of other American minoritized populations. Throughout the course, as an exercise in historical Interpretation and periodization, students will consider the question: Is this current moment "Jim Crow 2.0.?" This course fulfills Dietrich College's "Contextual Thinking" general education requirement.

79-215 Environmental Justice from Conservation to Climate Change

Intermittent: 9 units
What is environmental justice? Who are environmental justice activists, what do they believe, and how do they act? This course will explore these questions by reading, discussing, and comparing the biographies of famous activists (e.g. Rachel Carson, Chico Mendes, Ken Saro-Wiwa, Wen Bo, Berta C and #225;ceres, and Greta Thunberg) and not-so-famous, "everyday" people in order to understand how and why they have struggled against disproportionate exposure to pollution, government or corporate usurpation of life sustaining resources, or the loss of a home due to climate change. Course readings and discussions will use historical examples to understand connections between "social" problems such as racism and "environmental" problems such as climate change. We will evaluate how social identities, political ideologies, and ecological contexts have influenced the ideas and actions of environmental justice activists. Class discussions, short, written responses to readings, and a final project will encourage students to engage in critical analysis of environmental justice and self-reflect on their individual and collective responsibilities. This course fulfills Dietrich College's "Perspectives on Justice and Injustice" general education requirement.

79-216 Genghis Khan and the Mongol Empire

Intermittent: 3 units
This course examines the rise, rule, and impact of the Mongol Empire on global history. In the 13th century, Eurasia was shaken by a force contemporary chroniclers likened to an apocalypse. Within a few decades, horsemen under the command of Chinggis (Genghis) Khan swept out of the northeastern steppe to establish the largest land empire the world would ever know. Few events in world history have inspired such fear and awe. However, the Mongol period also ushered in the so-called pax Mongolica, the first period of sustained contact and exchange across Eurasia as people, technologies, arts, biodiversity, and ideas spread throughout the Mongol domains and beyond. Questions to be examined include: Who was Genghis Khan and how did he lead a little known nomadic people to conquer much of the known world? What cultural and technological innovations aided the Mongols rise and conquest? How did Genghis's successors rule their vast, diverse domains? What role did religion play in Mongol Eurasia? Why did a unified Mongol empire fall apart in such a relatively short period of time? And how did the Mongols and their empire help shape the world we live in today?

79-218 Tiananmen Square and Popular Protest in Modern China

Intermittent: 6 units
On June 4, 1989, the world watched as tanks rolled into Beijing's Tiananmen Square ending what had been six weeks of student-led protest calling for reform of the Chinese Communist Party and its policies. This was not the first time students had gathered at Tiananmen to demand political change. Exactly seventy earlier, student-led protests launched the May 4th Movement, a social and intellectual revolution that fundamentally changed China and helped birth both the Nationalist Party of Chiang Kaishek and Communist Party of Mao Zedong. This class examines the causes and consequences of popular protest in modern China. While the focus is on the protests of 1919 and 1989, we will also look at other popular protests, including the Cultural Revolution (1966-1969), Democracy Wall Movement (1979), post-Tiananmen protests among workers, farmers, and ethnic minorities (especially Tibetans and Uyghurs), and the current protests in Hong Kong.

79-219 Hong Kong, Taiwan and the Idea of "China"

Intermittent: 6 units
Starting with the core question, "What is China?", this mini-course explores the recent histories of Hong Kong and Taiwan to investigate questions of identity, nationalism, ethnicity, exceptionalism, colonialism, and historical memory in "Greater China." While both Hong Kong and Taiwan are generally considered to be "Chinese," neither ever has been fully included in the modern Chinese nation-state. The agreement that transferred Hong Kong from British rule to PRC control in 1997 enshrined the idea of "One Country, Two Systems," a guarantee that Hong Kong's political, legal, and economic systems would not be altered for fifty years. One Country, Two Systems has also been offered as a blueprint for "reunifying" Taiwan with Mainland China. However, in recent years publics in both Hong Kong and Taiwan not only increasingly resist political reunification with the PRC, but more and more identify themselves as citizens of either Hong Kong or Taiwan rather than members of a singular Chinese nation. This has led to mass protests in Hong Kong and calls for true independence in Taiwan. Other topics that may be discussed include subethnic identity and ethnic minorities in modern China and the Chinese diaspora.

79-220 Screening Mexico: Mexican Cinema, 1898 to Present

Intermittent: 6 units
This mini-course is a survey of Mexican cinema from its origins in silent film to the present. Some areas of focus will include documentary footage and films of the Mexican Revolution (1910-1920), films of the Mexican "Golden Age" (1930-1960), and "New Mexican Cinema" from the 1990s forward. We will explore cinema as a window on Mexico's changing social, cultural and political dynamics, and as a way to probe such topics as: changing conceptions of Mexican identity; political critique and revolutionary movements; and urbanization, migration and the "drug war" in contemporary Mexico.

79-222 China and the Second World War

Intermittent: 6 units
This course is an introduction to China's experiences during the Second World War. Although China's involvement in the war is often considered to be of secondary importance, it was in China that the war began (1937) and China was occupied longer than any other allied country. Throughout, sustained Chinese resistance ensured that 1.5 million Japanese troops could not be transferred to other war theaters. However, it came at great cost. Only the Soviet Union suffered more casualties during World War II, perhaps as many as 20 million lives lost. In this class we explore the roots of the Second World War in both China and Japan, trace the political and military history of the war, contemplate the terrible levels of violence that were inflicated upon the Chinese population, including violence committed by Chinese forces, seek to understand the social impact of the war, and think about the consequences of the war for China and the world, including the rise of Mao Zedong's Chinese Communist Party. We also explore the manner in which the war is commemorated in China and Japan and the role communal memory plays in galvanizing nationalism among both the Chinese and Japanese publics.

79-223 Mexico: From the Aztec Empire to the Drug War

Intermittent: 9 units
This course provides a survey of Mexican history and culture over avariety of periods, from the rise of the Aztec empire, to Spanish conquest and colonization, to national independence, to the Mexican Revolution and contemporary Mexico. A wide range of topics will be addressed, such as: race, ethnicity, and indigeneity; state formation and politics; national identity and the politics of memory; the border, migration, and the deportation regime; and the drug war. Students will discuss historical and anthropological scholarship on Mexico, but will also consider cultural documents of various kinds, like Mexican music, art, cinema and food. This course is interdisciplinary, bringing together the perspectives of both history and anthropology. A majority of readings for the course are primary documents-historical, but also cultural texts-and hence a good amount of time is spent considering issues around primary source interpretation in historical and cultural terms.This course stresses the importance of taking account of difference (social, cultural, historical) as we consider large questions about history, politics, and in some cases, policy.

79-225 West African History in Film

Intermittent: 9 units
West Africa is a vibrant, diverse, and rich region, which has had the largest influence demographically, culturally, socially, and linguistically on the Americas. This course will examine West Africa's history from the pre-colonial to the independence period. It will cover such topics as states vs. stateless societies, urbanization, trans-Saharan trade, Islamization, European interaction, the trans-Atlantic slave trade, colonialism, cash crops, missionaries, nationalism, and independence. Students will understand how this dynamic region changed over time as a result of internal factors, such as state formation, as well as external factors, interaction with Muslim and European traders. Students will also be exposed to the variety of sources used by historians to reconstruct West Africa's rich history. The course will use historical films by some of West Africa's most famous filmmakers, such as Ousman Sembene, to illustrate the diversity of the region and its historical change over time. Course includes two class meetings and mandatory film screenings on Wednesdays from 6:40-9:30pm. This course fulfills Dietrich College's "Contextual Thinking" general education requirement. Note to CFA Students: If the film-showing portion of this class conflicts with a theatre/stage placement, please know that alternative screening times can be arranged on a case-by-case basis. If you have any questions or concerns, please contact the instructor directly.

79-226 African History: Earliest Times to 1780

Intermittent: 9 units
A beginning point for this course will be the question: how do historians reconstruct history when few written sources are available? Breaking disciplinary boundaries, the course will draw on linguistics, "climateology," archaeology, and anthropology to reconstruct dynamic social, cultural, political, and economic processes in Africa before the arrival of Europeans and before the availability of written source materials. When written sources are available, the course will interrogate them to illuminate the changes that occurred in African societies during the early period of contact with Europeans. Lastly, by focusing on long-term processes, such as economic specialization, urbanization, and Islamization, the course will begin to put the slave trade in an African-centered perspective.

79-227 Modern Africa: The Slave Trade to the End of Apartheid

Intermittent: 9 units
The course is designed to give students an understanding and appreciation of African history and culture from the "inside out." Though it deals with the period of European expansion in Africa, it is centered on African language/ethnic groups, villages, and individuals as historical actors who daily make collective and personal decisions to pass down, innovate, and borrow practices, technology, spiritual systems, etc. in the face of social, political, and economic realities. The course is also designed to get students thinking critically about how historians select and interpret sources to construct and reconstruct history at these different levels. This course fulfills Dietrich College's "Intercultural and Global Inquiry" general education requirement. It also satisfies one of the core requirements for the African and African American Studies minor.

79-229 The Origins of the Palestinian-Israeli Conflict, 1880-1948

Intermittent: 9 units
This course considers the historical origins of the contemporary Arab-Israeli conflict, beginning with the decline of the Ottoman Empire and the rise of Arab nationalism and Zionism in the late 19th century and emphasizing the period of the British Mandate over Palestine (1920-1948). Students will move beyond textbooks to explore primary source documents, maps, photographs, biographies and historical testimony. For five weeks in the middle of the semester, students will immerse themselves in an extended role-playing exercise, "The Struggle for Palestine, 1936," an elaborate simulation game linked to Barnard College's "Reacting to the Past" program. Students portraying British examiners, specific Arab and Zionist characters and journalists will recreate the activities of the 1936 Royal Commission that came to Palestine to investigate the causes of an Arab rebellion and Arab-Jewish strife. This historical reenactment experience constitutes an exciting pedagogical opportunity for delving deeper into the topic material than regular coursework allows. All the role-playing will take place during regular class time, but students should be aware that they will need to devote outside time for preparation and research. Outstanding attendance is also a requirement. Regular classroom activity resumes at the end of the five weeks. The goal of the course is for students to develop a nuanced understanding of the varying goals and priorities of all the actors in Mandate Palestine. Running throughout the course is the question, was peace ever possible?

79-230 The Arab-Israeli Conflict and Peace Process Through 1948 to Present

Intermittent: 9 units
The course begins with the origins of both Zionism as an intellectual, European movement and of Arab and then Palestinian Arab claims for sovereignty in the early 20th century. The course interrogates not only the histories of ideologies that led to revolution and violence in the modern history of Palestine and Palestinians and of Zionism and Israel, but also the very notions of 'conflict' and 'peace.' It examines ideas of state and nation as well as practices of Ottoman and then British imperialism and Zionist settler colonialism in the territory that became Palestine, then Eretz Israel, and now Israel and the occupied Palestinian territories. Throughout the semester, students will explore how these ideas and practices are linked to the development of violence, armed struggle and a myriad of nationalist and religious-nationalist ideologies as they came to be understood by Palestinian Arabs, Zionist settlers, Palestinian citizens of Israel, Islamists, and Israeli religious/national groups. Students are tasked with considering the historical social, political, cultural, and religious implications of these discourses and practices. We will make use of documentary and other primary sources and texts, including poems, excerpts from literature, memoirs, film footage, posters, and other forms of media. By the end of the semester, students will be able to analyze and discuss the historical significance of the multi-faceted ideologies and motivations held by actors involved in the armed struggle movement(s) in Palestine and Israel, and the shifting nature of nationalisms as dependent upon locations, time periods, and understandings of history and politics. This course fulfills Dietrich College's "Intercultural and Global Inquiry" general education requirement.

79-232 Arabian Peninsula Environmental History

Intermittent: 9 units
This course is ONLY offered at Carnegie Mellon in Qatar. This course will look at the history of the Arabian Peninsula from a fresh perspective, examining human/environmental interactions over a long stretch of time. In contrast to the way that Arabian history is typically taught in academia, this course will take the pre-Islamic period of Arabian history (al-jahiliyya) as seriously as the post-Islamic period, and will focus on continuities between the two periods as much as discontinuities. What is more, while conventional histories of the Arabian Peninsula focus on political and religious affairs, this course will try to understand Arabian history on a deeper level by focusing on the lifeways of the Arabian people, including pastoralism, oasis "bustan garden" agriculture, fishing and pearling, and shifting patterns of long-distance trade. What is more this course will draw heavily from material from other disciplines, especially medical sciences, to better understand patterns of change over time. Finally, this course will examine to what degree these older patterns of human/landscape interactions are still valid for the Arabian Peninsula today, which has undergone a transformation almost unparalleled in world history due to the discovery natural gas and oil.

79-234 Technology and Society

Intermittent: 9 units
How has technology shaped human society? And how have human beings shaped technology in return? This course investigates these questions across history-from stone tools, agriculture, and ancient cities to windmills, cathedrals, and the printing press; from railroads, electricity, and airplanes to atom bombs, the internet, and the dishwasher. In analyzing these tools, we will explore the dynamic relationships between technological systems and the social, political, religious, artistic, and economic worlds in which they emerged. We will also pay particular attention to technology's effects, asking both who benefited from and who was harmed by technological change. By the end of the course, students will be able to reflect critically on how humanity chooses which technologies to exploit and how human societies have been transformed by these choices. This course fulfills Dietrich College's "Humanities" general education requirement.

79-237 Comparative Slavery

Intermittent: 9 units
This course will examines the pervasive, world-spanning institution of human slavery. Although the time frame this course deals with is broad - from the rise of complex societies in the ancient world to slavery-like labor systems in the modern era - this class will focus more thoroughly on a few case studies, especially slavery in the Middle East and sub-Saharan Africa, the US, and the Caribbean. These disparate examples will be related to a number of core themes, including race, class, family, gender, religion, national identity and underdevelopment.

79-238 Modern African American Film: History and Resistance

Intermittent: 6 units
This course explores the historical and contemporary impact of resistance on and in African American film during the twentieth and twenty-first centuries. We will consider how filmmakers use narrative and aesthetics to represent, address, and combat anti-blackness, attend to filmmaking itself as a potential act of resistance, and cultivate our own "oppositional gazes" as spectators and critics. The five films we will watch are: · Within Our Gates (dir. Oscar Micheaux, 1920) · Do the Right Thing (dir. Spike Lee, 1989) · Daughters of the Dust (dir. Julie Dash, 1993) · The Watermelon Woman (dir. Cheryl Dunye, 1996) · Moonlight (dir. Barry Jenkins, 2016) Access to the films and any supplemental readings will be provided; unless otherwise stated on the syllabus, students will be expected to carefully study this material prior to each class. Though there will be brief lectures contextualizing each film's production and reception history, the majority of our meeting times will be spent on student-led discussion. Assignments include weekly written responses, a final project, and classroom participation. Because of the nature of the course topic and the content of the films, participation requires extended engagement with fictional depictions of issues including, but not limited to, lynching, sexual violence, police brutality, homophobia, and intraracial antagonism. Students are free to contact me at any point in the term if this becomes an issue.

79-239 History of the American Working Class

Intermittent: 9 units
This course will examine the transformation of the American working class from its preindustrial origins to the recent period of deindustrialization, gentrification, and the onset of the Corona Virus. It will emphasize the changing relationship between owners, managers, and workers, the role of the state, and the impact of gender, race, and ethnicity. More specifically, this course will not only analyze the factors that facilitated and/or impeded working class solidarity, but assess the impact of the working class upon the development of American history, including the recent recognition of previously maligned human service workers as "essential workers" during the upheaval of COVID-19.

79-240 Development of American Culture

Intermittent: 9 units
This is an introductory survey of American history from colonial times to the present. The course focuses on cultural history instead of the more traditional emphasis on presidents, wars, and memorizing facts or timelines. The major theme of the course is the changing meaning of freedom over three centuries. Required readings include several short books and historical documents, which will be paired with class lectures to provide students with context needed to think about and understand America's cultural history. Assignments will include three short essays and a final research project on a form of popular culture of the student's choosing, developed over the course of the semester through three short blog posts.

79-242 African American History: Reconstruction to the Present

Intermittent: 9 units
This course explores changes in the African American experience from the end of the Civil War to the emerging era of Joe Biden and Kamala Harris. Through an examination of a wide range of scholarly and popular debates in African American life and history, this course will emphasize transformations in both inter- and intra-race relations; economic mobility as well as economic inequality; and forms of political engagement and grassroots movements for social change. We will explore these developments under the impact of the segregationist regime; the Great Migration; the rise of the urban-industrial working class; increasing residential segregation; growth and expansion of the middle class; and the fluorescence of the Modern Black Liberation Movement. Students will compare the dynamics of the contemporary Black Lives Matter Movement with earlier 20th century grassroots social and political movements in African American and U.S. history. Finally, based upon a mix of primary and secondary sources and lectures, students will write a series of short analytical essays; and establish their own unique interpretation of key issues in Black History.

79-243 The Civil War in American Memory

Intermittent: 6 units
The American Civil War remains among the most venerated and fought over stories in American history. This class explores those debates. Why was the war fought? Was the Confederate cause noble? Did the North oppose slavery? What did freedom mean? How does a nation erect racial justice? What does it mean to fly the Confederate flag or confront a Confederate monument today? Tackling these ongoing debates (and more) from the war (1861-65) itself until today, this course grapples with why the war continues to be one of the most defining moments in U.S. history - 150 years later - and what that means for our past and present as a bi-racial democracy. This course is open to all students.

79-244 Women in American History

Intermittent: 9 units
This course is a survey. It examines U.S. history through the eyes of women and gender. It begins in the colonial era (1600s) and runs chronologically to the present. It covers topics such as witchcraft, the story of Pocahontas, women's work, motherhood, slavery, and much more. We will look at the lives of individual women, as well as trends among women, paying attention to questions of race and class. At the same time, we will explore changing concepts of gender, meaning ideas about what women are or should be. Finally, the course asks: how different does American history look when we factor in women and gender?

79-245 Capitalism and Individualism in American Culture

Intermittent: 9 units
This small discussion course traces ideas about individualism and capitalism in the U.S., from colonial times to the present. We will focus on three main themes: 1) the relationship between capitalism, work, and identity; 2) changing definitions of success and failure; and 3) the historical origins of students' attitudes toward 1 and amp; 2. In short, we will study the economics and emotions of the American dream: how class, race, gender, occupation, and ambition shape our identities. Readings include "The Autobiography of Benjamin Franklin," poems by the enslaved writer Phillis Wheatley, studies by Alexis de Tocqueville and Max Weber, writings of Frederick Douglass, Henry David Thoreau, Charlotte Perkins Gilman, Andrew Carnegie's classic essay "Gospel of Wealth," an essay by Malcolm Gladwell, Arthur Miller's "Death of a Salesman," and Sarah Lewis's "The Rise," a book about failure and ambition. Grading is based upon a readings journal, participation in discussion, three short essays and a longer final paper.

79-246 Industrial America

Intermittent: 9 units
This course examines the transformation of America into an urban industrial society during the 19th and 20th centuries. The transformation of work, culture, and politics will receive close attention, but the course will primarily focus around how workers defined their own labor and changes in the culture of work over time. This course will investigate how race, class, and gender informed workplace relations as well as how immigration and migration changed the nature of American work. Through lecture, discussion, and three short writing assignments we will uncover how workers defined America.

79-247 African Americans, Imprisonment, and the Carceral State

Intermittent: 9 units
The mass incarceration of people of African descent has emerged as one of the most daunting issues in contemporary U.S. society and politics. But too often discussions of this important phenomenon proceeds without sufficient historical perspective. Thus, this course explores the history of African Americans in the nation's prison system from the emancipation of some four million enslaved people following the Civil War through recent times. Specifically, we examine the process by which the nation's prison population shifted from predominantly white inmates during the mid-19th century through the inter-World War years to majority African Americans and other people of color by the closing years of the 20th century. In addition to examining the role of law, policing, and racist social policies and practices, students explore the lived experiences of imprisoned people, with an emphasis on the impact of class and gender as well as racial considerations. Along with selected primary documents, assigned readings include a series of scholarly case studies on the carceral experiences of black men and women in the North and South during the industrial and emerging postindustrial eras in African American and U.S. history. Finally, students will write a series of short essays on particular facets of African American life in the American prison system.

79-248 U.S. Constitution & the Presidency

Intermittent: 9 units
This course explores the changing role and powers of the American Presidency under the Constitution, from the founding era through the twentieth century. After absorbing drafting and ratification debates, we will focus on how particular presidents (Washington, Lincoln, FDR, Nixon) established or expanded the executive power and how particular conflicts (the Civil War, the "Court Packing" plan, Watergate) restructured or restricted the presidency. Readings will include the U.S. Constitution (of course), selections from The Federalist Papers, and short books including Daniel Farber's "Lincoln's Constitution" and Cass Sunstein's "Impeachment: A Citizen's Guide." Grades will be based on three short papers, a final paper, and daily preparedness and participation in group discussion. This course fulfills Dietrich College's "Contextual Thinking" general education requirement.

79-249 20th Century U.S. History

Intermittent: 9 units
This survey course covers the history of the United States from Reconstruction to today through by focusing on migration, race and ethnicity, and citizenship or national belonging. Chronologically organized, the course centers key themes and issues of social, economic, and political importance in both past and present. We will also explore how historical events and their documentation change in meaning and importance over time, and what forces and influences shape these realities. Overall, we will consider the causes, processes, and experiences shaping the arrival of different immigrant groups to the United States at different historical moments. More specifically, we will follow migrations of different groups of people, like African Americans, north and westward; European immigrants into coastal port cities and beyond; Mexican bracero workers into agricultural industries; Chinese laborers work experiences in diverse economic settings; and more. We will apply critical lenses toward movements like Americanization and try to understand different groups of citizens' divergent experiences with national belonging. We will also interrogate the logics, values, and symbols that shaped ideas regarding ethnic, racial, class, and gender difference, particularly as they were used to characterize difference regarding citizenship.

79-250 Voting Rights: An Introduction

Intermittent: 9 units
Did you know that American citizens have no right to vote? None. The United States is one of the only constitutional democracies in the world that does not enshrine this right in its founding charter. Not only did the nation's founders punt on creating one, social movements have also never succeeded in creating one. What, then, have voting rights activists won over the centuries? And how and why has an affirmative right to vote never been achieved? Starting with the U.S. Constitution and working forward to the present, this course will help you make sense of all the accusations swirling in the news about voter fraud, voter suppression, voter theft, voting rights, and all the other things no one ever taught you about the world's oldest democracy. This course is open to all students.

79-251 COVID-19: What History Can Teach Us

Intermittent: 3 units
For many, the COVID-19 Pandemic feels like a rupture in time - a disaster unprecedented in scale and impact. Yet one-hundred years ago, the Influenza Pandemic of 1918 killed between 17 million and 50 million people. That virus infected approximately a third of all human beings on the planet and #8212; some 500 million people. Since then, humanity has faced a series of influenza epidemics and other global catastrophes, from world wars to HIV-AIDS. Like COVID-19, those crises were shaped by pre-existing forms of inequality and discrimination based on race, gender, sexuality, religion, nationality, and other forms of identity. Pandemics affect everyone, but not equally. For many of the world's poorest and most oppressed people, the COVID-19 pandemic feels less like a rupture than an escalation of long-standing inequalities. In the United States, the racial disparities of the pandemic reflect the long history of systemic racism. What can we learn from the past about how to cope with our current crisis? How can we confront the inequities and injustices of the world in the midst of such a crisis? This course will offer a historical lens on many of the most urgent and difficult questions that we face as a result of COVID-19.

79-252 "Harriet": Harriet Tubman, Slavery, and the Underground Railroad

Intermittent: 6 units
Most Americans who know and love Harriet Tubman know she escaped enslavement, led herself and more than 60 people out of bondage via the Underground Railroad, gave instructions on getting to freedom to 50 or 60 more people, and became a suffragist. However, the many biographies, children's books, and even the biopic "Harriet" about Tubman are all virtually silent on a very important chapter of her life: during the US Civil War, Harriet Tubman worked as a nurse, cook, spy, and scout for the US Army Department of the South. This course will look at two parts of Tubman's life, her enslavement in the Maryland Eastern Shore and freedom via the Underground Railroad, as well as her military service in coastal South Carolina and participation in the Combahee River Raid, which freed 756 blacks enslaved on nine rice plantations six months after the Emancipation Proclamation went into effect. We will watch the biopic "Harriet" and discusses where it does and does not accord with historical sources about Tubman's life. And, we will tour the "From Slavery to Freedom" exhibit at the Senator John Heinz History Center to learn more about the Underground Railroad, particularly in Western Pennsylvania.

79-253 Imperialism and Decolonization in South Asia

Intermittent: 9 units
Home to a diversity of cultures, languages, and histories, the population of South Asia is linked through a common experience of European colonialism in the nineteenth and early twentieth centuries. Virtually all of the contemporary nation-states of South Asia achieved independence from European colonial powers in the middle of the twentieth century, most between the 1940s and 1960s. With a focus on South Asian history, this course will include introductory sessions on pre-colonial interaction and the early modern world. The bulk of the course will focus on colonialism, nationalism, and decolonization from the early nineteenth century to the mid-twentieth century. In addition to assessing the legacies of colonialism in the present day, the course will interrogate the differences between colonial and postcolonial experiences across the South Asian world. It will further examine the challenges and trials confronting the new states "after" decolonization, in particular, their search not only for new political frameworks to replace the colonial structures they had discarded, but also for solutions to mitigate the issues of social integration, inter-state conflict and regional co-operation.

79-255 Modern Ireland: Politics and Culture from the Famine (1847) to Today

Intermittent: 9 units
[Note: students who have already taken this course under its former number 79-255 and former titles, Irish History, or Politics, Religion, and Conflict in the 19th and 20th Century Ireland, may not enroll.] This course studies the political, economic and social development of Ireland across its long nineteenth century. Beginning with the social and economic effects of the Famine of the 1840s, it studies Ireland's growing incorporation into the British-centric global economy, the growing role of Catholicism in Irish politics, the cultural ferment of the late nineteenth century and the events leading up to formal independence in 1922. Following on from this, the course reviews the development of the two Irelands (the Republic of Ireland and Northern Ireland), the rise to hegemony of Fianna F and #225;il and the Ulster Unionist Party, the politics of gender and sexuality in two of western Europe's most conservative societies, violence in Northern Ireland, and rapid economic, social and political changes since the 1990s. Ultimately, this course seeks to use Ireland as a case study for understanding the history of small nations and modern European nationalism as well as economic and political development on the periphery of Europe. This course fulfills Dietrich College's "Humanities" general education requirement.

79-256 Sex, Guns, Rock, and Skinheads: Youth Rebellion in Europe, 1960-1990

Intermittent: 9 units
Between 1960 and 1990, young Europeans rebelled against the conservatism of their parents and politicians. In 1968, they exploded into the streets in capitalist Paris and socialist Prague. In West Germany and Italy, a minority of left-wing radicals took up the gun to bring former Nazis and Fascists to "justice." Young people demanded and practiced sexual liberation. Young women marched for their emancipation and led the struggle to legalize abortion. Young Europeans also contributed to the liberalization of anti-homosexual laws. The British Beat revolution rocked the world with its innovative music, anti-establishment lyrics, shocking fashions, and wild lifestyles. By the 1980s, youth rebellion had taken on disturbing trends with the emergence of right-wing Skinheads and a surge in drug addiction. The course combines lecture and discussion of readings and films. Students will write three essays (1000 words each) based on class assignments. They will write a final essay (1500-1700 words) based on their own research into the press, fanzines, films, etc. (in place of a final exam).

79-257 Germany and the Second World War

Intermittent: 9 units
This course, taught in Somerset prison, covers many aspects of the war unleashed by the Third Reich: its origins; Hitler's ideology and war plans; the course of the war; major military operations; the Holocaust; Nazi occupation of Europe; resistance to Nazism; and life inside Germany. It concentrates on the Wehrmacht's strategies, decisions, and its relationship with Hitler and Nazi organizations. (The Wehrmacht was the Third Reich's "defense/armed forces" but the term is generally used to refer to its army.) We will investigate the role of the Wehrmacht in Nazi/SS crimes against humanity, including genocide, fighting partisans, killing civilians, and the treatment of Soviet POWs. We aim to understand how, where, why, and when the Wehrmacht came to have "dirty hands." Course readings; chapters from Ben H. Shepherd, Hitler's Soldiers: The German Army in the Third Reich; chapters from Nicholas Stargardt, The German War: A Nation under Arms, 1939-1945; primary documents. Written assignments (10 in total): weekly 500-600 word responses to questions based on course readings. The course combines lecture, discussion, in-class group exercises, and a debate.
To all students registering for this PEP course, please fill out this brief questionnaire so that the instructor may address your questions/concerns in advance: https://forms.gle/j4kjshSrRzSaNFbu6.

79-259 Black Rice

Intermittent: 6 units
Rice originates in only two places in the world: Africa and amp; Asia. Most historians agree that West African rice and its cultivation and amp; processing technology were transmitted to colonial SC and amp; GA via the trans-Atlantic slave trade, laying the foundation for the commercial rice industry and making South Carolina rice planters the richest planters in British North America before the American Revolution. Though some historians don't agree.... In "Black Rice," we'll learn about how rice technology in West Africa's Upper Guinea Coast for subsistence, how it was transferred to the antebellum US South, and why technology in precolonial West Africa and enslaved people as skilled, not just brute labor are so, so controversial! In addition, we will watch the March 3, 2023 performance of "Unburied; Unmourned, Unmarked: Requiem for Rice" by the New York Philharmonic at Lincoln Center and discuss the libretto on which the project was based.

79-260 Nazi Germany

Intermittent: 9 units
This course covers Nazism in Germany from its beginnings as a small movement after the First World War through its rise to power in 1933 to its fiery destruction and defeat in 1945. What were the sources of its appeal as a political party? How did the Nazi regime suppress the political opposition in 1933? Why did so many ordinary Germans collaborate with the regime in its hunt against political, religious, sexual, and racial enemies? Why did they support the regime to the bloody end of the most murderous war in history?

79-261 The Last Emperors: Chinese History and Society, 1600-1900

Intermittent: 9 units
This course is an introduction to late-imperial "Chinese" history and society with a focus on the Qing dynasty (1644-1912). We begin by examining the Qing not just as the last of China's imperial dynasties but also as an early-modern, multi-ethnic empire that included Mongolia, Tibet, and Xinjiang. In fact, China's "last emperors" were actually Manchus from northeast Asia. Secondly we investigate the social, economic, intellectual and demographic developments that transformed late-imperial China prior to the coming of the West. Thirdly, we examine Qing responses to a string of nineteenth-century disruptions, including but not limited to western imperialism, that threatened to not only end the dynasty but also challenged the very tenants of Chinese civilization. Lastly, we will look at the fall of China's imperial system, the end of empire, and the post-imperial struggle to reformulate the state and re-imagine society for the twentieth century. This course fulfills Dietrich College's "Humanities" general education requirement.

79-262 Modern China: From the Birth of Mao ... to Now

Intermittent: 9 units
This course is an introduction to major themes in twentieth-century Chinese history, including the transition from empire to nation, revolution, social change and modernization, western and Japanese imperialism, the rise of the party-state, Chinese socialism, economic liberalization and the so-called "Chinese Dream." The first half of the class is devoted to the period between the fall of the imperial system and the founding of the People's Republic of China (1911-1949). If the victory of the Chinese Communist Party and development of the socialist state are to be considered in historical context, it is necessary to first understand the political, cultural, economic and intellectual currents that immediately preceded them. During the second half of the course, we will examine the Maoist period (1949-1976). We will investigate the Chinese Communist Party as both a state-building institution and an engine of social transformation, and consider the tensions these dual roles produced. Finally, we will look at the Reform Period (1978-present), and reflect on a newly robust China's attempts to come to terms with its own recent past and what the consequences might be for both China and the world.

79-263 Mao and the Chinese Cultural Revolution

Intermittent: 9 units
This course is an in-depth examination of China's "Great Proletarian Cultural Revolution" (1966-1976), one of the most impactful and bewildering events of the twentieth century. It started when Mao Zedong announced that enemies had infiltrated the Communist Party that he led. Soon students were attacking their teachers, teenagers in army uniforms were raiding homes and destroying remnants of "feudal" and "bourgeois" culture, and armed fighting had erupted among factions of ordinary Chinese people. Why? What were the political and social dynamics of Maoist China that propelled it along this violent trajectory? What was everyday life like during the Cultural Revolution, an event that could be both terrifying and empowering for those that lived through it? What were the social, political and cultural consequences? How has the Cultural Revolution been judged in China and the west, and are their other possible interpretations? This class will explore these questions from a variety of perspectives and sources, including documents, literature, memoir, film, academic writings, visual arts and performing arts.

79-264 Tibet and China: History and Propaganda

Intermittent: 9 units
This course is an introduction to the "Tibet Question," the dispute over whether Tibet should be part of China, an independent nation-state, or, as the current Dalai Lama now advocates, something in between. "History" often serves as the battleground on which competing visions of the nation are fought - who should be included and excluded, where "natural" boundaries begin and end. This almost always requires a process of simplification in which inconvenient details are forgotten or repurposed in the service of national agendas. The "Tibet Question" is a telling example. In this class, we investigate the historical relationship between "China" and "Tibet" from the 13th century through the present, and note the ways advocates on both sides of the "Tibet Question" have constructed historical narratives (propaganda) in support of their political positions. We will also discuss the prospects for a political solution and consider the lessons the "Tibet Question" may hold for understanding other outstanding "historical" disputes.

79-265 Russian History: Game of Thrones

Intermittent: 9 units
How are states built? How are empires forged? This course, beginning with the first settlements of tribal nomads in the ninth century and ending with the abolition of serfdom in 1861, surveys the grand 'game of thrones' in Russian history. It explores the building of a Russian Empire from the first princely kingdoms at murderous war with each other to the emergence of a strong state, headed by a tsar and centered in Moscow. Over the centuries, we make the acquaintance of Mongol marauders, greedy princes, and brave peasant rebels, as well as Ivan the Terrible, Peter the Great, and the long succession of reformers and reactionaries who occupied the Russian throne. Students will be challenged to think critically about social injustice and resistance, and the relationship between ethnicity, serfdom, land ownership, and empire. This course fulfills Dietrich College's "Contextual Thinking" general education requirement.

79-266 Russian History and Revolutionary Socialism

Intermittent: 9 units
This course covers an epic set of events in Russian history beginning with the emancipation of the serfs in 1861 and ending with the death of Stalin in 1953. Spanning almost a century of upheaval and transformation, it examines the terrorist and populist movements against the tsar, the growth of urbanization and a new working class, the great general strike and revolution of 1905, the Russian revolution in 1917, and the Communist Party and amp;#39;s attempt to build a new socialist society amid the wreckage of the old. We will discuss the struggle for power within the Party in the 1920s, Stalin's triumph over his opponents, the wrenching processes of collectivization and industrialization, and the "Great Terror." The course will explore the Soviet role in World War II, the shattering losses, and the death of Stalin in 1953. This course meets the Gen Ed requirement for "Humanities"

79-267 The Soviet Union in World War II: Military, Political, and Social History

Intermittent: 9 units
On June 22, 1941, Hitler invaded the Soviet Union. German troops surrounded Leningrad in the longest running siege in modern history, reached the outskirts of Moscow, and slaughtered millions of Soviet civilians. Of the 6 million Jews murdered by the Nazis, almost 2 million were killed on Soviet soil. Over 26 million Soviet citizens died in the war. Eventually, the Red Army came back from defeat to free the occupied territories and drive Hitler and amp;#39;s army back to Berlin. Using history, film, poetry, veterans' accounts, documentaries, and journalism, this course surveys the great military battles as well as life in the occupied territories and on the home front. It highlights the rise of fascism, the Stalinist purges of the Red Army, and the Nazi massacres of the civilian population.Occasional film screenings may be required.

79-268 World War I: The Twentieth Century's First Catastrophe

Intermittent: 9 units
This course offers a comprehensive retrospective of the First World War in Europe. Guiding questions will be: How did a containable crisis between Austria-Hungary and Serbia become the most murderous war Europe had ever experienced? How did the war spill over into the Middle East? Why did the US enter the war? Why did every General Staff follow unimaginative military strategies that turned the war into a bloody horror for soldiers? How did the war affect women's situation and rights? How did the war become a Total War that fomented social and political revolution and led to the downfall of four Empires?

79-269 Russian History: From Socialism to Capitalism

Intermittent: 9 units
Beginning with Stalin's death in 1953, this course focuses on the efforts of a new group of Soviet leaders to eliminate the repression of the Stalin years and to create a more democratic socialism. It will examine the reforms of Khrushchev and the reaction against them, the long period of Brezhnev's rule, and the hopeful plans of Gorbachev. Finally, it will survey Gorbachev's loss of control, the collapse of socialism and the Soviet Union, and the growth of "wild west" or "gangster" capitalism. We will look at the rise of the oligarchs and the impact of the capitalist transition on ordinary people. The course provides essential background for anyone interested in understanding Russia's place in the world today and its relationship with the West. This course fulfills Dietrich College's "Intercultural and Global Inquiry" general education requirement.

79-270 Anti-Semitism Then and Now: Perspectives from the Middle Ages to the Present

Intermittent: 9 units
This course will examine the history of anti-Jewish hatred and violence from the Middle Ages through the present. The course will focus on representative case studies, texts, and films. These will include pre-modern incidents of "fake news" such as the medieval rumor of "blood libel" that unleashed massacres and mass expulsions of Jews from countless communities. In examining the rise of modern anti-Semitism, we shall focus on debates over Jewish assimilation and citizenship and consider the popular impact of the print media's dissemination of conspiracy theories of Jewish world domination, including the infamous forgery, "The Protocols of the Elders of Zion." We will also examine cases of mass anti-Jewish violence, known as pogroms, in Eastern Europe and Russia, and the genocidal onslaught against European Jewry by the National Socialist regime. Finally, we will discuss the contemporary global resurgence of anti-Semitism.

79-272 Coexistence and Conflict: Muslims, Christians and Jews in Spain and Portugal

Intermittent: 9 units
In Medieval Spain and Portugal, Islam, Judaism and Christianity coexisted in a situation distinguished by cooperation and exchange, as well as by friction, rivalry and violence. In this course, we shall explore the complexity of this unique historical encounter, as well as its role in shaping debates over modern Iberian and global identities, and historical memory. We shall discuss topics such as: Inter-ethnic collaboration and violence; Jewish-Christian disputations; the exclusion and expulsion of religious and ethnic minorities; as well as Muslim and Jewish presence in present day Spain and Portugal. Historical documents, literary texts, film, musical traditions, as well as contemporary political and cultural debates will be discussed to enhance familiarity with the topic.

79-273 Jews and Muslims in History

Intermittent: 9 units
What is the history of Muslim-Jewish interaction beyond the Palestinian-Israeli conflict and the images of violence in the Middle East that permeate the media? The overarching goal of this course is to explore this question through close study of the history of Jews and Muslims who lived as neighbors, in cooperation as well as in conflict in the Middle East, North Africa and Europe, from the rise of Islam in the seventh century to the present day. Our sources will include works of scholarship, primary source texts such as religious queries and government documents, journalistic materials, memoirs, and films.

79-275 Introduction to Global Studies

Spring: 9 units
We live in an increasingly interconnected world, one in which our everyday actions have repercussions across vast distances. To understand this ever-denser web of connections, we must think beyond simplistic accounts of globalization as a uniformly positive, negative, or homogenizing process. Economic crisis, impoverishment, rising inequality, environmental degradation, pandemic disease, and irredentist movements are just as much a part of the story as are technological innovation, digital communication, global supply chains, cultural exchange, the promotion of human rights, and the rise of cosmopolitan values. This course aims to equip you with an interdisciplinary toolkit for thinking critically about the many dimensions of globalization (economic, social, political, cultural) and for engaging thoughtfully with differing experiences of them. By examining how globalization connects and shapes the everyday lives of people around the world, including our own, we will establish a foundation both for your advanced coursework in Global Studies and for your lifelong education as a globally aware professional and citizen. This course fulfills Dietrich College's "Intercultural and Global Inquiry" general education requirement.

79-276 Beyond the Border

Intermittent: 9 units
In this course we will consider the historical emergence and transformation of the U.S.-Mexico border, as much as an idea as a physical boundary. Our explorations will be far-ranging: from the initial encounters of Christopher Columbus and Hern and #225;n Cort and #233;s with indigenous populations, to social, cultural and political dynamics of the borderlands in subsequent centuries; from the experiences and practices of cross border migrants, to contemporary immigration debates and policies surrounding migration, border control and walling, and the deportation of unauthorized migrants. In addition to course readings, we will screen several Mexican films that are centrally concerned with the dynamics of bordering and border-crossing. This course fulfills Dietrich College's "Perspectives on Justice and Injustice" general education requirement.

79-278 How (Not) to Change the World

Intermittent: 9 units
It's often said that the road to hell is paved with good intentions. What, then, can we learn by excavating some of those pavers and interrogating the theories of change that underlie them? And what can we learn from more successful attempts to enact social change? In this course, we will use the tools of history, anthropology, and critical theory to examine various efforts to 'change the world'. From top-down social engineering to neoliberal 'market citizenship' to grassroots organizing, case studies will challenge us to detect theories of change (even when they are concealed) and evaluate their consequences (intended and otherwise). With those lessons in mind, we will then apply our tools to the theories of change that we enact, often unwittingly, as members of a university. Which roads are we paving and where do they lead?

79-280 Coffee and Capitalism

Intermittent: 9 units
What role has coffee played in connecting people and places to capitalist markets and consumer cultures? What are the economic, social, and environmental consequences of these connections? How did espresso change from an "ethnic drink" to something served at McDonalds? Why do college students (and professors!) hang out in coffee shops? This course will answer these questions and more by using coffee to learn about the history of capitalism, and capitalism to understand the history of coffee. We will follow the spread of coffee and capitalism across the globe, with excursions to places where people grow coffee (Ethiopia, Yemen, Indonesia, Brazil, and Costa Rica), and also where they drink coffee (Seattle, Tokyo, Seoul, New York, and Berlin). In the process, we will confront global problems linked to economic inequality, trade, gender relations, and environmental degradation. Course meetings will combine interactive lecture, group discussions, and mini-presentations. Assignments will include journal responses, ethnographic observations, and writing a short script that tells a story about coffee and capitalism.

79-281 Introduction to Religion

Intermittent: 9 units
Religion can be understood from the "outside," through the academic lenses of history, sociology, psychology, philosophy, etc., and from the "inside," listening to the experiences and reflections of those who practice various faiths. The course will examine major religious traditions from several perspectives and begin to explore such topics as the relationship between religion and science, faith and reason, religion and moral values, and religion in public life. This introduction is designed for students with a general interest in religion, as well as those contemplating a Religious Studies minor.

79-282 Europe and the World Since 1800

Intermittent: 9 units
This course will introduce students to topics of historical and contemporary relevance in European society and culture from the nineteenth century to the present. We shall focus especially on Europe's place in shaping debates of major international importance and #8212;both new and old and #8212;about topics such as: colonialism; migration; religious, ethnic, and national identity; Islamophobia; and antisemitism. Throughout we will pay special attention to the situation of inhabitants. past and the present, who have been considered outsiders or "others" in European society. In addition to class lectures, students will view films and listen to music related to the main themes of the course, in addition to reading and discussing historical texts.

79-283 Hungry World: Food and Famine in Global Perspective

Intermittent: 9 units
The science and technology of the Green Revolution in the second half of the 20th century were heralded as a miracle. Agricultural science promised seeds, peasants, companies, governments, scientists, economists, exporters, and planners would work together to support growing populations, especially in the post-colonial world. The human population on Earth reached 6 billion by the year 2000; 7.6 billion were estimated around 2017. The United Nations predicts 8.6 billion by 2030. Awareness of living in this unique period of human history brought new debates among scholars, practitioners, and planners thinking about the critical role of agriculture and development on Earth. How can we conceptualize, hope, and plan for best possible outcomes for a human population that depends on agriculture and development? How has the legacy of the Green Revolution encouraged (or betrayed) public enthusiasm for innovative fixes? This interdisciplinary course will use methods and case studies drawing on History, Historical Demography, Anthropology, Cultural Studies, Regional Studies, Geosciences and Agricultural Sciences, and International Economic Development. If students wish to pursue a particular thematic or regional interest, there will be room in this course to explore particular cases in depth.

79-288 Bananas, Baseball, and Borders: Latin America and the United States

Intermittent: 9 units
This course will examine the tumultuous and paradoxical relationship between Latin America and the United States from the time of independence to the present, with an emphasis on Mexico, Central America, and the Caribbean during the Cold War (1945-1989) and its aftermath (1990s-present). We will literally talk about bananas, baseball and borders; the title also alludes to the key dimensions of the relationship we will study: economic, cultural, and geopolitical. We will learn about the actions of U.S. and Latin American government leaders and diplomats along with many other kinds of people including activists, artists, and journalists; athletes, movie stars, and scientists; and migrant workers, tourists, and drug traffickers. Mondays and Wednesdays will feature interactive lectures, videos and in-class activities; Fridays will be entirely devoted to student-driven discussion. Evaluation will be based on participation; two written analysis of historical documents, and a final reflection. This course fulfills Dietrich College's "Intercultural and Global Inquiry" general education requirement.

79-289 Animal Planet: An Environmental History of People and Animals

Intermittent: 9 units
Why do modern societies go to great lengths to protect some animals and slaughter others? Why do some cultures make pets of animals that other cultures turn into a meal? What are the environmental ramifications of hunting, domestication, and trading animals? Is there a connection between human pandemics like COVID-19 and animals? Why are there so many cute animals inhabiting social media? These are some of the questions that we will seek to answer as we trace changes in human and #8212;animal relationships over time. We will explore these themes through both texts and visual representations (art, film, photography) of animals. Evaluation will be based on active participation in class discussions, submission of weekly field notes, and a final curated exhibit of images of people and animals.

79-290 The Slave Passage: From West Africa to the Americas

Intermittent: 9 units
"The Slave Passage" begins among flourishing, technologically advanced, and globally connected regions of Western Africa before the advent of the trans-Atlantic slave trade. It tells the painful story of African captives during the Middle Passage, piecing together the historical record to recognize their suffering aboard the slaving vessels and their multiple strategies of resistance. Students will study slave narratives, slave ship logs, and autobiographies of former enslaved people, as well as analyze films depicting the Middle Passage and New World enslavement.

79-291 Innovation and Entertainment: A Business History of American Popular Culture

Intermittent: 9 units
This course will examine one topic in popular culture and entertainment per week, from newspapers to streaming services. The course will consider these industries through the lens of business history, documenting innovation and the development of entertainment as commodities. While we will trace many changes over the years, we will primarily focus on the birth of new industries. Guiding questions will be: How did the country's economy, society, and politics structure the development of popular culture? How did performers and entrepreneurs develop industries around new innovations in popular culture? And how did popular culture shape the country's economy, society, and politics?

79-292 China and the West

Intermittent: 9 units
This course examines the global history of China from the time of Marco Polo to the era of Xi Jinping, with particular emphasis on the political, social, and economic dimensions of how "China" and "the West" have interacted over the past three centuries. How have European and American writers, travelers, and political figures thought about China over time? How have their Chinese counterparts thought about the West? What have been the dominant narratives about Sino-Western relations, and how do these compare with how China and the West actually interacted? We will cover major topics such as the Opium Wars and Cold War geopolitics as well as more mundane issues, including the everyday lives of foreigners in China and the experiences of Chinese abroad. Using government documents, trade records, memoirs, and other sources, students will come to situate Sino-Western relations in a new historical perspective as they examine the dynamics of transnational interaction and reflect critically on how the present informs the construction of narratives about the past. This course fulfills Dietrich College's "Intercultural and Global Inquiry" general education requirement.

79-293 Inward Odyssey

Intermittent: 9 units
This course is ONLY offered at Carnegie Mellon in Qatar. Inward Odyssey will explore world history by examining it through the outward-looking eyes of travel writers, on the assumption that travelogues, though supposedly written about the "other," in fact provide crucial insights about the mindset of the culture that produced them, and often serve as a vehicle for cultural self-exploration or even self-criticism. In terms of content, this course is intended to overlap with World History, Islam and the European World, and US-Arab Encounters. However, this course is intended to be a skills course, designed not to teach students about specific historical periods, but rather to give students the tools they need to conduct their own critical explorations into the historical past.

79-295 Legacies of Fascism and Anti-Fascism:From 1930s Spain to Russia's War on Ukraine

Intermittent: 3 units
Russia's war on Ukraine has elicited divergent responses from different political and civil actors and scholars around the globe. Many of these responses are steeped in the history of the 1930s and World War II, including around questions of fascism and anti-fascism. In this course we will inquire whether the history of fascism and anti-fascism might provide us with any useful tools to address the current war in Ukraine. We will start by examining the history of the rise of fascism and of antifascist response, beginning with Mussolini's march on Rome in 1922 and the impact of Italian fascism on Spanish fascism and the outbreak of the Spanish Civil War (1936-1939). The final part of the course will focus on the origins of the war in Ukraine. We will hear from guest speakers, including relatives of volunteers and experts on the Spanish Civil War, as well as experts on the history of Ukraine, including Ukrainian scholars and refugees. Monday, 10/31 from 4:40pm-7:00pm-HH B131 Tuesday, 11/1 from 4:40pm-7:00pm-HH B131 Wednesday, 11/2 from 4:40pm-7:00pm-HH B131 Thursday, 11/3 from 4:40pm-7:00pm-HH B131 Saturday, 11/5 from 11:30am-5:00pm-BH A36

79-296 Religion in American Politics

Intermittent: 6 units
Religion figures prominently in American politics, especially in congressional election years. A common view, reinforced by some media and polling organizations, holds that "religiosity" correlates with conservative politics, but that's highly misleading, as religious people are in fact all over the political map - even on issues like abortion, same-sex marriage, and what is taught in public schools. Thomas Jefferson's mention of a "wall of separation" between church and state indicates that religious institutions are generally kept separate from government in America, but religious motivations have always played an important part in our politics. This course will provide a historical perspective on religion in public life down to the present day, including religion's influence on political parties and public policies, and the boundaries set by the Constitution on such activity. This course satisfies one of the elective requirements for the Religious Studies minor.

79-297 Technology and Work

Intermittent: 9 units
In recent years, conversations about the relationship between technology and work seem to have been conducted with particular fervor: claims of revolutionary ease and freedom sit side-by-side with dystopian visions of exploitation, surveillance, and alienation. Will technological development lead to a new "sharing economy" or widespread deskilling? Will it bring general prosperity or enrich the few at the expense of the many? These concerns - though especially apparent today - are by no means new. In this course, we will examine their history, focusing in particular on North America and Europe in the past two centuries. We will examine the ways in which new technologies - from the assembly line to the washing machine to the personal computer - transformed what it meant to work, and how workers, their families, and the companies who employed them reacted to these changes. Our historical actors will include famous figures like Henry Ford, but also unnamed women, children, people with disabilities, and racial and ethnic minorities. Throughout, we will pay attention to who benefitted, who was harmed, and what broader economic, cultural, or social purposes these technologies were designed to serve.

79-298 Guns, Gun Cultures, and Gun Violence in American History

Intermittent: 6 units
This course traces the development of gun cultures and gun-related policy and law in the United States from the colonial era to the present. Students will be expected to synthesize perspectives from social history, ethnography, public health, criminology, policy analysis, and legal scholarship. They will also engage the critical examination of popular culture and media representations of guns and gun violence. Particular emphasis will be placed on changing views about the authority of the government to intervene in the manufacture, ownership, and use of guns, as well as the best way to balance individual and collective interests in a pluralistic society.

79-300 Controversial Topics in the History of American Public Policy

Intermittent: 9 units
This course traces the development of US domestic public policy, the growth of the federal government, and the changing relationship among citizens, states, and the federal government over time. We begin with an examination of the current policy landscape and then go back in time to understand how we got to where we are today. We very quickly discover that our current political predicaments are not accidental. Particular people or groups across the political spectrum have worked hard to shape public policy at various critical points in history and have reaped tremendous benefit, even if their influence makes the overall system unstable or unworkable today. We identify critical moments of crisis or change in American politics, examine the imaginaries and policy levers available to people at that time, and explain how policy decisions were made. Students will gain a clear understanding of how interests and political will have been cultivated and mobilized in the past, which can offer them useful models for advancing their own priorities and those of their generation. Topics covered currently include health care and health insurance, abortion, and immigration. This course fulfills Dietrich College's "Contextual Thinking" general education requirement.

79-301 History of Surveillance: From the Plantation to Data Capitalism

Intermittent: 6 units
Our awareness of surveillance has been dramatically heightened over the past few years. From Edward Snowden's revelations about the U.S. National Security Agency's data collection infrastructure to the extent to which companies like Facebook and Google monetize our personal information, surveillance has become one of the most controversial political issues of our time. In this course, we will place these developments in context, examining the long history of surveillance in the United States. We will begin with the 18th-century plantation "overseer," who was charged with ensuring the productivity and obedience of slaves under his watch. We will then move on to explore the emergence of commercial surveillance in the 19th century, which sought to gather intelligence on the credit worthiness and moral worthiness of businessmen in a rapidly growing, and increasingly impersonal, economy. Next, we will examine the shifting focus of surveillance from the late 19th century to the present, as it expanded from immigrants and criminals to include industrial workers, political radicals, civil rights activists (most notably Martin Luther King), the poor, and ultimately, all of us. Today, anyone who has a cell phone in their pocket, surfs the Internet, keeps up with friends through social networks, makes purchases with a credit card, uses membership cards, travels, or even just spends time in public spaces ought to assume that their movements, purchasing habits, communication metadata, social connections, and Internet browsing histories are being recorded, stored and analyzed for a variety of governmental and commercial purposes. In the final week of the course, we will debate the implications of these incursions into our public and private lives.

79-302 Killer Robots? The Ethics, Law, and Politics of Drones and A.I. in War

Intermittent: 9 units
Unmanned aerial vehicles (drones) have become a central feature of the United States' global counterterrorism strategy since September 11, 2001, and autonomous weapons systems (often called "killer robots" by critics) are increasingly being integrated into military arsenals around the world. According to proponents, drones and autonomous weapons systems are much safer than manned systems, so accurate that they can be used to target individuals and detect threats in real time, and efficient and inexpensive enough to be used for long-term surveillance and protection missions around the globe. According to critics, the use of lethal autonomous weapons systems is problematic because of the obfuscation of historically and legally accepted chains of accountability and responsibility, as well as the difficulty of translating complex decision-making processes including ethical and moral ones into computer code. This course will evaluate these issues through the lenses of law, politics, morality, history, and military strategy.

79-303 Pittsburgh and the Transformation of Modern Urban America

Intermittent: 6 units
[Note: students who have already taken this mini course under its previous number 79-303 and title may not enroll.] This course will focus on the transformations, both positive and negative, of Pittsburgh and the Pittsburgh region in the period from 1945 through the present. It will explore the following themes: the rise of industrial Pittsburgh, the redevelopment of the city in the Pittsburgh Renaissance; urban renewal and its consequences; the collapse of the steel industry and its impacts; the development of an Eds/Meds service economy; air, land and water environmental issues; and the city's changing demography.

79-306 Fact into Film: Translating History into Cinema

Intermittent: 9 units
From the very beginning, film has provided a window into the past. But how useful are the images we see through that window? For every person who reads a work of history, thousands will see a film on the same subject. But who will learn more? Can written history and filmed history perform the same tasks? Should we expect them to do so? How are these two historical forms related? How can they complement each other? This course will draw examples from across the history of film in order to examine how the medium of film impacts our understanding of facts and events, the ways that film transfers those facts to the screen, and how that process affects the creation of historical discourse. Films may include such titles as The Fall of the Roman Empire, The Gunfight at the O.K. Corral, Saving Private Ryan, World Trade Center, Enemy at the Gates, Lagaan and Hero.

79-308 Crime and Justice in American Film

Intermittent: 9 units
Films dealing with criminal activities and criminal justice have always been popular at the box office. From the gangsters of the Thirties and the film noir of the Fifties to the more recent vigilante avenger films of Liam Neeson, the film industry has profited from films about crime and its consequences. How those subjects are portrayed, however, tells us a great deal about larger trends in American history and society. Every imaginable type of criminal activity has been depicted on screen, as have the legal ramifications of those acts. But these films raise profound questions. What is the nature of crime? What makes a criminal? Are there circumstances in which crime is justified? How do socioeconomic conditions affect the consequences? How fair and impartial is our justice system? Perhaps most importantly, how do depictions of crime and justice in popular media influence our answers to these questions? This class will utilize a variety of films to discuss the ways in which popular media portrays the sources of crime, the nature of criminals, the court and prison systems, and particular kinds of criminal acts. Films to be screened may include such titles as The Ox-Bow Incident, Out of the Past, 12 Angry Men, Young Mr. Lincoln, Brute Force, The Equalizer, Jack Reacher and Minority Report. By thoroughly discussing these films and related readings we will be able to trace the various changes in attitude towards crime and justice in America over the last century.

79-309 The Chinese Revolution Through Film (1949-2000)

Intermittent: 9 units
This course is about both film and history. It is not a detailed history of film, but rather introduces some key issues of modern Chinese history and examines how that history is treated in film. Most of the films are made in China (including Taiwan and Hong Kong) but some are produced in the west. Topics that may be explored include the rise of the Communist Party, life in Maoist China, the Cultural Revolution, the Cold War/anti-imperialism, depictions of China's minority peoples, and the Reform-era under Mao's successors. Along with feature movies, we may view documentaries, propaganda films, TV shows and even music videos. In addition to providing a general history of the period, accompanying readings and assignments explore the social context and methodology of the films while developing critical skills in writing, analysis, and historical imagination.

79-312 War and Peace: A History of Peace Movements

Intermittent: 9 units
We generally assume war is a constant in our history and in the modern world. However, in every era there have been voices attempting to understand, explain and ultimately prevent it. In the modern world there has been a great deal of debate about the relationship of violence, capitalism, colonialism, empire, and racism to war. We will examine some of these debates among peace activists. Advocates for peace have attempted to build movements addressing the factors leading to war. What kinds of efforts have been made for a more peaceful world and how have they fared? We will examine how world leaders, business people, civil rights, and other peace activists have thought about war and peace. We will examine case studies of select wars and select peace movements.

79-313 "Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration

Intermittent: 6 units
What is home? What does it mean to belong? What does it mean to be mobile? Is mobility a privilege or a curse? How do experiences of migration, exile, and displacement shift one's understanding of home? This course examines the modern patterns of mobility and displacement, with a focus on the US and Europe at particular moments during the 19th,the 20th, and 21st centuries. We will focus on several case studies to illustrate broader concepts: the connection between the formation of nation-states and the rise of exclusionary citizenship; the emergence of 20th-century modern legal concepts such as "refugee" and "asylum"; the influence of the Cold War on the immigration policies in the US; and the criminalization of border-crossing.

79-314 How Do We Remember? The Politics and Cultures of Memory

Intermittent: 9 units
What is the relationship between an individual person and collective memories? How do societies "remember"? This course proposes an interdisciplinary approach to the relationship between memory and history. It explores various ways in which societies have mobilized their remembrances of the past for political and economic ends in the present; how and whose memory began to matter in a global 20th century; and how individual testimonies have highlighted the role of body, experience, trauma, and nostalgia for writing new, more inclusive and heterogenous histories. In the first part of the course, we will read excerpts from works by historians, sociologists, and anthropologists about cultural and collective memory. In the second part of the course, we will analyze how the politics of memory intermesh at a local and global scale, via a set of case studies that focus on: the memory of the Shoah (the Holocaust) in post-1945 Western and Central Europe; political violence, civil war, and reconciliation in post-1990 Guatemala; and the role of remembrance and testimony for claims of moral retribution in the aftermaths of colonialism (the Mau Mau revolt in colonial Kenya and the long-term efforts of the British government to conceal their violent repression of the anticolonial struggles). This class will follow the format of a seminar. The professor will give short lectures each week in order to introduce the readings and place them within larger debates, but the course will mainly be discussion-oriented. This course fulfills Dietrich College's "Contextual Thinking" general education requirement.

79-315 The Politics of Water in Global Perspective

Intermittent: 9 units
Water is necessary for all forms of life on Earth. The purpose of this course is to introduce students to social and political aspects of water, using in-depth case studies that draw on a variety of perspectives. Examples of regional water projects we'll study include traditional tank irrigation in South India; international negotiations along the Nile River; and the U.S. Government in negotiation with native activists and fisheries on the Columbia River. In addition to regional variety, readings will explore a variety of themes, for example, water and gender; water and armed conflict; and water and private companies versus public management. By the end of this course, students should be able to articulate their own answers to these questions: How have global organizations and participants characterized, enacted, and addressed problems of water supply and delivery for those who need it most? How do particular regions reflect global trends in water resource development, and how might these diverge from global trends? How have social and environmental studies in the literature of development come to understand the problem of water? One set of readings is assigned each week. Students should be prepared to discuss each week's readings in a thoughtful way during class meeting time.

79-316 Photography, the First 100 Years, 1839-1939

Intermittent: 9 units
Photography was announced to the world almost simultaneously in 1839, first in France and then a few months later in England. Accurate "likenesses" of people were available to the masses, and soon reproducible images of faraway places were intriguing to all. This course will explore the earliest image-makers Daguerre and Fox Talbot, the Civil War photographs organized by Mathew Brady, the introduction in 1888 of the Kodak by George Eastman, the critically important social documentary photography of Jacob Riis and his successor, Lewis Hine, the Photo-Secession of Alfred Stieglitz, the Harlem Renaissance of James VanDerZee, the precisionist f64 photographers Ansel Adams, Imogen Cunningham, and Edward Weston, and other important photographers who came before World War II. The class will be introduced to 19th century processes, such as the daguerreotype, tintype, and ambrotype, as well as albumen prints, cyanotypes, and more.

79-317 Art, Anthropology, and Empire

Intermittent: 9 units
This seminar will explore the anthropology and history of aesthetic objects, as they travel from people and places sometimes labeled "primitive" or "exotic" to others, whose inhabitants deem themselves "civilized," "modern," or Western. First, we will consider twentieth-century anthropological attempts to develop ways of appreciating and understanding objects from other cultures and in the process to reconsider the meaning of such terms as "art" and "aesthetics." Then we will discuss several topics in the history of empire and exoticism. Finally, we will consider attempts by formerly colonized populations to reclaim objects from museums, and to organize new museums, aesthetic styles, and forms of artistic production that challenge imperialism's persistent legacies.

79-318 Sustainable Social Change: History and Practice

Intermittent: 9 units
If you wanted to change the world, who would you ask for guidance? Mahatma Gandhi? Rachel Carson? Nelson Mandela? In this interdisciplinary course, we will examine the history of efforts to create sustainable social change. Through a series of targeted case studies, we will examine the successes and failures of notable leaders, past and present, who strove to address social problems nonviolently and to create lasting improvements in fields such as education, healthcare, and human rights. In keeping with the example of the people we will be studying, we will bring our questions and our findings out of the classroom through a variety of creative, student-driven experiments in sustainable social change.

79-319 India Through Film

Intermittent: 6 units
Bollywood films attract hundreds of millions of viewers, not just in India but throughout the world. The name "Bollywood" makes it seem that the Indian film industry is a junior partner, merely an echo of Hollywood. But more films are made in Mumbai every year than in Los Angeles. And Mumbai is only one of many film hubs in India. The rich diversity of Indian cinema speaks to the equally rich history of India itself. This course uses Indian movies to examine several key themes in India's history. We will focus on the twentieth century and on questions of democracy, diversity, and development. This course includes a mandatory film screening on Wednesday evenings beginning at 6:30pm.

79-320 Women, Politics, and Protest

Intermittent: 9 units
This course examines the history of women's rights agitation in the United States from the early nineteenth-century to the present. It investigates both well-known struggles for women's equality and #8212;including the battles for women's voting rights, an Equal Rights Amendment, and access to birth control and #8212;and also explores the history of lesser-known struggles for economic and racial justice. Because women often differed about what the most important issues facing their sex were, this course explores not only the issues that have united women, but also those that have divided them, keeping intersectionality and women's diversity at the center of the course. This course is open to all students.

79-321 Documenting Human Rights

Intermittent: 9 units
This course will teach students about the origins of modern human rights and the evolution of methods to document the extent to which these rights are being upheld or violated. The need to understand and document human rights issues is at the center of the most pressing current events. From threats to democracy and civil rights to work holding perpetrators of mass harm accountable in legal proceedings to efforts to quantify and advance economic, social, cultural, and environmental rights, making human rights violations visible is fundamental to achieving a more just world. We will begin with an overview of the history of human rights, the main philosophical and political debates in the field, and the most relevant organizations, institutions, and agreements. We will then delve into specific cases that highlight methodological opportunities and challenges, including: the identification of mass atrocity victims, the disappeared, and missing migrants; efforts to estimate civilian casualties in war; the documentation of police brutality and other human rights violations with smartphones; as well as the use of satellite imagery and drone footage for the documentation of genocide, environmental rights, and war crimes. We will critically assess the technical challenges that arise in each context and how the human rights and scientific communities have responded. After reviewing these cases, we will conclude by reflection on why the documentation of human rights actually matters and what happens to evidence once it is gathered. Students will then take what they've learned and do two multidisciplinary group projects, one involving the document of a rights violation in Western Pennsylvania and the other involving an international situation. This course fulfills Dietrich College's "Perspectives on Justice and Injustice" general education requirement.

79-322 Stalin and the Great Terror

Intermittent: 9 units
Joseph Stalin has been vilified and praised, damned and worshipped. He left behind a mixed and complex legacy. He created an industrialized modern economy in the Soviet Union and won a great and painful victory over the Nazis. At the same time, he built a police state, sent millions to labor camps, and destroyed the possibilities for socialist democracy. When he died, thousands of Soviet citizens wept at his funeral and the prisoners in the camps toasted his death. This course will examine Stalin, the man, and Stalinism, the phenomenon. Using history and film, we will explore one of the most complicated and influential dictatorships of the 20th century.

79-323 Making Modern Cities

Intermittent: 9 units
Cities have been a feature in the landscapes of human settlement for nearly 6000 years. This course will examine the origins and evolution of cities by examining the role of urban areas in the economic, cultural, political, and environmental history of the world. The main line of inquiry for this course emphasizes the culture of cities and the processes of urbanization that give rise to them. Students will explore why and how cities form, the functions they serve, the ways of life they support, and the problems and opportunities to which they give rise. Cities are socially and politically contested spaces, and observers of urban life have long-sought to understand the process of urbanization and the consequences of living in cities. Some argue that cities represent the crowning achievement of modernity; others suggest that cities are isolating and alienating, fostering discord, rather than social cohesion. The course integrates work by historians, urban planners, architects, political scientists, geographers, and sociologists to provide a comprehensive set of tools to understand and analyze modern urban life.

79-324 #MeToo: Naming and Resisting Gender Violence

Intermittent: 6 units
#metoo represents a sea change in society's response to gender-based violence. This course addresses gender-based violence as a public health and amp; human rights issue, focusing on the U.S. and asking where we are, and how we got here. It will delineate the legal and social definitions of gender violence, explore how those definitions function both positively and negatively, and examine the long history of protest that has culminated in this moment. Come join the conversation! This course is open to all students.

79-325 U.S. Gay and Lesbian History

Intermittent: 6 units
US Gay and Lesbian History offers an overview of the changing context and circumstances of sexual minorities in American culture. From early constructions of moral opprobrium, criminal deviance or medical pathology, the LGBT community emerged in the twentieth and twenty-first century as a political constituency and a vital part of contemporary society. Students should be aware that this course will necessarily address issues of intimate relations and sexuality as well as broader historical issues.

79-326 Shall We Dance? Culture, Politics, and Movement in the 20th Century

Intermittent: 6 units
Waltzes and flash mobs, hula and swing, disco and breakdance: this course will examine the history and practice of these and other popular dance movements across the course of the twentieth century. In doing so, we will pay particular attention to the ways in which dance both shaped and reflected major moments of political, cultural, and social change. Dancing bodies were used to justify imperial ambitions, explore new kinds of gender relations, and both uphold and upend racial hierarchies, making dancers key - if underappreciated - participants in the century's tumultuous history. The course will include a mix of lecture and discussion, drawing on scholarly analyses, archival sources, films, literature, images, and live performances. Students will also be asked to explore at least one new dance form for themselves and reflect on the experience.

79-328 Photographers and Photography Since World War II

Intermittent: 9 units
Invented in 1839, photography was a form of visual expression that immediately attracted a large public following. Starting around 1900, photography was practiced with two dominant strands. One of these firmly believed in the power of photographs to provide a window on the world, and was led by Lewis Hine, whose documentary photographs for the National Child Labor Committee helped to ameliorate living and working conditions for thousands of immigrant children. The other strand adhered to the philosophy of Alfred Stieglitz who adamantly affirmed that photographs were first and foremost reflections of the soul and were art objects, equal to painting, drawing and sculpture. These two schools of thought guided photographers throughout the twentieth century. This course explores in depth the tremendous range of photographic expression since World War II and examines in particular the contributions of significant image-makers such as Helen Levitt, W. Eugene Smith, Robert Frank, Diane Arbus, Garry Winogrand, Charles "Teenie" Harris, Cindy Sherman, Carrie Mae Weems, Nan Goldin, James Nachtwey, and many others. Classes include a slide lecture, student presentation, and video segments that introduce a focused selection of images by major photographers in an attempt to understand their intentions, styles, and influences. As available, students will be expected to make one or more visits to photography exhibitions on view in Pittsburgh (locations to be announced at the first class.)

79-329 LGBTQ+ History

Intermittent: 9 units
This class introduces and discusses LGBTQ history over time, drawing cases and readings from a number of cultures and timeframes. It introduces students to the concept of sexuality as an area of historical inquiry as well as introducing students to the methods and the questions that have engaged historians in this area. This introductory course is designed for all interested students and non-majors alike, as well as those contemplating a Gender Studies minor.

79-330 Medicine and Society: Health, Healers, and Hospitals

Intermittent: 9 units
How have notions of health and healing changed over time in the United States? Why are doctors seen as professional "heroes"? Why are hospitals so central to patient care and professional training? How has American healthcare developed into its present form? This course explores the history of American medicine and its relationship to American society. By exploring major developments in the history of American medicine and public health, students will examine the voices of historical actors, including physicians, patients, activists, policymakers, and researchers. In analyzing these voices, students will learn what was at stake as Americans confronted diseases and struggled to explain and cure them. Students will also examine medical research, education, disease patterns, patient experiences, and technologies from the colonial period to the present day. Readings include a range of primary accounts and secondary sources of medicine and health in America.

79-331 Body Politics: Women and Health in America

Intermittent: 9 units
[Note: Students who have taken 66-121, First Year Seminar: Body Politics: Women and Health in America, may not enroll.] This course takes a topical, intersectional approach to the history of U.S. women's health in the nineteenth and twentieth centuries. It is less about governmental politics, although we do some of that. Rather, it sees bodies as cultural texts through which power is built and contested. The course covers topics such as the history of anatomy, menstruation, reproductive rights, body image, mental health, sexuality, violence, childbirth, and menopause. We explore how science and American culture both have constructed these issues over time (some of it is super whacky!), while also examining women's organizing around them. This course is open to all students and majors alike, and it also satisfies one of the core requirements for the Gender Studies minor.

79-333 African Americans, Race, and the Fight for Reparations

Intermittent: 9 units
By the onset of the 21st century, African American history and interdisciplinary programs in Black studies had emerged at the center of our reinterpretation of the American experience. And with this new understanding of the nation's history there has been a growing interest in the relationship of history to public policy, race, human injustice, and resulting redress movements in comparative and historical perspective. Accordingly, this course will not only explore the case for reparations by analyzing the inequities of enslavement, Jim Crow, and post-industrial capitalism. It will examine the ongoing fight for reparations among people of African descent from the early postbellum years after the Civil War through the Black Lives Matter Movement in recent times. In addition to examining the experiences of Blacks in the United States, however, this course will consider other experiences around the globe: Native Americans, Mexican Americans, and Japanese Americans within the United States; the Holocaust in Germany; Japan's so-called "comfort women" system of sexual exploitation; and South Africa's movement toward reconciliation and reparations since the fall of apartheid.

79-337 Educational Policy and "School Choice": Historical and Contemporary Perspectives

Intermittent: 6 units
Fierce battles have been fought over education policy throughout American history. Parents, teachers, students, and everyday Americans have sought to position schools to meet often conflicting goals. This course introduces students to historical and contemporary perspectives on the rise of charter schools and school privatization, debates over religion in the classroom, legal questions surrounding segregation and forced bussing, as well as fundamental political shifts in who controls and funds public schools.

79-338 History of Education in America

Intermittent: 9 units
Americans have long understood schools both as mechanisms for inculcating communal values and as instruments for social reform. Schools have been alternatively described as pillars of democratic society and as authoritarian institutions for managing deviance. Institutions of education - whether schools, colleges, or universities - figure prominently in discussions of inequality and discrimination, opportunity and meritocracy. This course provides an introductory historical survey of American educational ideas and institutions. From debates in the 17th and 18th centuries over the proper balance of religious and secular education to fierce battles today over the role of the federal government, citizens have been politically mobilized through their concerns about education. By understanding the complicated history of American educational ideas and institutions, this course prepares students to engage critically with ongoing debates about the curriculum, vouchers, charter schools, and national standards.

79-339 History of Juvenile Delinquency & Juvenile Justice

Intermittent: 9 units
Course description to be added soon.

79-340 Juvenile Delinquency & Film: From "Boyz N the Hood"(1991) to "The Wire"(2002-08)

Intermittent: 6 units
How have American films portrayed juvenile crime, drug use, gang violence, and law enforcement responses (especially police and prisons) to juvenile crime and violence? How have American films portrayed individual juvenile delinquents, their families, and the communities in which they live? Do films vividly capture or distort the "realities" of juvenile crime and the operations of law enforcement? This course uses feature films from the late 20th and early 21st centuries, as well as social science and historical readings, to explore these issues. The course is run as a colloquium, with students playing central leadership roles in launching and guiding class discussions.

79-342 Age of Crusading, 1000-1800

Intermittent: 9 units
What does it mean to become a crusader and #8212;or be crusaded? How did a pope's sermon galvanize over 100,000 people to leave their homes and undertake a perilous journey across Europe to a place many had never seen? Why did one military campaign in 1096 initiate a seismic shift in the articulation (and acceptance) of Christian holy war? What started as a series of expeditions to Jerusalem and #8212;which we now call the "crusades and #8212;later extended to the cities of Constantinople and Cairo, to the regions of Southern France and Italy, and even to the Baltic Sea and the Americas. In this course, we will trace crusading ideology and knighthood from their roots to their fullest expressions throughout the Middle Ages and into modernity. These individuals who "took up the cross" and #8212;or encouraged others to do likewise and #8212;radically shaped the ideas of identity and piety in Latin Christendom. Perceiving themselves as God's agents in an apocalyptic age, crusaders came to fight Muslims, Jews, pagans, heretics, and even their fellow Christians. They also served as heroic inspiration in bardic song and courtly literature across Spain, France, and England. As scholars we will explore the perspectives of the invaders and those who were invaded, thereby (re)imagining how people responded to the crusaders' presence and their accompanying violence. Our sources will include prophecies, sermons, scripture, poetry, art and archeological remains, and film. Together, we will approach this challenging topic critically, yet respectfully, while completing short analytical papers and a set of reflective quizzes. This course is open to all students, requires no prerequisites, and may be used to fulfill the Religious Studies minor.

79-343 Education, Democracy, and Civil Rights

Intermittent: 9 units
What is the relationship between education and democracy? By examining a series of case studies at the intersection of education and the civil rights movement, this course will prepare students to approach contemporary educational debates as historically-informed critical thinkers. The controversy surrounding charter schools, vouchers, the common core, and the role of standardized testing cannot be understood outside the long history of debates regarding the relationship between education and democracy. Are schools meant to perpetuate the status quo? How did both traditional and more radical forms of education advance the struggle for civil rights? What role have students played in advancing civil rights and democracy? While exploring these questions, we will also partner with local high school students and teachers to bring our learning beyond the classroom.

79-345 Roots of Rock & Roll

Intermittent: 9 units
This course is about open source, collaborative innovation and the impact of social and technological change on American music. We will spend the first half on early "remix" music (slave songs, Anglo-Appalachian ballads, ragtime, and Depression era blues and country). After studying Bessie Smith, Woody Guthrie, Lead Belly, Hank Williams, and other early artists, we'll spend the second half on revolutionaries like Chuck Berry, Bob Dylan, Jimi Hendrix, and Janis Joplin. The format is informal lecture and discussion. Assignments include reading two books plus some articles, listening to short Spotify playlists, and writing three short essays. This course fulfills Dietrich College's "The Arts" general education requirement.

79-346 U.S. Political Films and Satire

Intermittent: 9 units
A longtime course taught in election years, this version focuses on Hollywood satires of the presidency. Satire means critique as much as humor, often more funny-strange than funny ha-ha. We will watch films attentively (no devices allowed during screenings) and communally, hence the class meets Tuesday evenings. We will study each film for two weeks; one session discussing readings/learning the history of the time it was made, then watching/discussing the whole film the following week. Attendance will be required and essential. Students will learn how (and why) to take notes during screenings, sometimes working together in class to shape their notes and discussions into individual papers. Screenings include 1930s classics "Gabriel Over the White House" and the Marx Brothers' "Duck Soup," Cold War thrillers "The Manchurian Candidate" and "Seven Days in May," and the dark comedies "Dr. Strangelove" and "Being There." One final film will be chosen by the students. Readings include short books and PDF articles. Grading emphasizes attendance and attentive participation, notetaking, and short essays. No prior knowledge of history or film is needed, and there are no prerequisites.

79-350 Early Christianity

Intermittent: 9 units
This course examines the origins of Christianity in historical perspective. Using both Christian and non-Christian sources from the period, we will examine how and why Christianity assumed the form that it did by analyzing its background in the Jewish community of Palestine, its place in the classical world, and its relationship to other religious and philosophical traditions of the time. We will also examine historically how the earliest Christians understood the life and message of Jesus, the debates about belief and practice that arose among them, and the factors influencing the extraordinary spread of the movement in its earliest centuries. This course satisfies one of the elective requirements for the Religious Studies minor.

79-352 Christianity Divided: The Protestant and Catholic Reformations, 1450-1650

Intermittent: 9 units
At the dawn of the sixteenth century, most western Europeans shared a common religious identity as members of the Roman Catholic Church. Within less than two decades, this consensus began to crumble, and the very fabric of western culture was irrevocably altered. By 1550, Europe was splintered into various conflicting churches, confessions, sects, and factions, each with its own set of truths and its own plan for reforming the church and society at large. This period of rapid and unprecedented change in western history is commonly known as the Reformation. Though this term has traditionally referred to the birth of Protestantism, it also encompasses the simultaneous renewal and reform that occurred within Roman Catholicism. This course will survey the Reformations of the sixteenth century, both Protestant and Catholic, examining the causes of the Reformation, the dynamics of reform, and its significance for western society and culture. In the process, we will analyze such on-going problems as religious persecution and the accommodation of dissent, the relationship between religion and politics, and the interactions between ideology and political, social, and economic factors in the process of historical change.

79-353 Lock 'em up! Imprisoning Delinquent Youth, 1820s to the Present

Intermittent: 6 units
[Note: students who have already taken this course under its former number 79-353 and former title, Imprisoning Kids: Legal, Historical, and Moral Perspectives, may not enroll.]Can young lawbreakers be rehabilitated, or should they be removed from society to prevent them endangering others? Since the 1820s, reformers, philanthropists, and state officials in the Western world have wrestled with the question of how to reduce juvenile crime and turn delinquents into good citizens. The institutions and policies they created reflected their conceptions of young criminals, their backgrounds and families, their gender and their race. How did experts develop a body of knowledge about at-risk youth, what practices did they put into place, and what spaces did they build to house and contain the children? How have the children themselves responded, developing a sense of their own identity through compliance with or resistance to reformers' intent? In this course, we will explore ideas, practices, and institutions created to save juvenile delinquents, presented in reports and studies as well as fiction and film. Students will read and view a variety of primary and secondary sources from North America and Europe from the early nineteenth to the late twentieth centuries. Assessment will include participation in class discussion, short written assignments, and a final project.

79-355 Fake News: "Truth" in the History of American Journalism

Intermittent: 6 units
Scandal, conspiracy, and partisan propaganda have been among the stuff of media ever since newspapers first appeared in America, and now they figure prominently in electronic media as well. The question "What is truth" is not just a matter of philosophical speculation, but a critical issue in contemporary life, from elections to pandemics to climate change and war. Officials at the highest levels make dubious claims, and find media outlets to support them - all driven by motivations other than a commitment to truth. This course is literally "ripped from the headlines" examining conflicts over credibility in print and online in the context of historical experience. We'll explore ways of determining when news really is "fake" and when it's more likely to be "an inconvenient truth."

79-357 Science and the Body

Intermittent: 6 units
The human body has been always an object of fascination. Across time and space, people have wondered what lurks beneath the skin, why we get sick or remain well, and how to explain human variation. The methods used to investigate these questions have, however, varied widely. In this course, we will explore that diversity - from the dissection of medieval corpses to 19th century phrenology to contemporary biohacking - examining how different communities have sought to study, control, and change their bodies over the past several hundred years. In doing so, we will focus on how these scientific efforts were shaped by the political, cultural, and economic values of their times. We will also pay attention to the profound and often ongoing effects of these experiments, particularly on the people who served - both willingly and unwillingly - as their "human subjects."

79-359 Truth, Lies, and Propaganda: A Historical Inquiry

Intermittent: 9 units
For many commentators, the election of Donald Trump in November 2016 marks the beginning of the "post-truth" era, in which reality is no longer knowable, or even relevant. While this narrative certainly captures the unease that many Americans feel, it is historically inaccurate. There never was a time in the past when we could readily discern truth from falsehood without difficulty. The goal of this course is to examine the social history of truth. We will explore the concept of truth in philosophy and science; the evolution of methods for discovering facts about the world; the centrality of trust in knowledge production; and the innumerable ways that facts have been questioned, manipulated, discredited, purposefully ignored, and fabricated over the past several centuries. The course will include case studies from science, law, politics, war, art, journalism, and history.

79-360 Crime, Policing, and the Law: Historical and Contemporary Perspectives

Intermittent: 9 units
This seminar will critically explore the development of the American criminal legal system from the colonial era to the present. Students will learn how the present system took shape and what they can do to make it fairer and more effective in the future. Students will analyze the role of race, class, and gender in policy decisions that have created the American criminal legal system; how these factors play into the differential enforcement of laws in various communities; and how they affect outcomes in the legal system. Students will understand the history of social movements that have emerged to advocate for changes in our criminal legal system, including an analysis of when they have been successful and when they have not. Topics covered will include slave patrols, the 19th century origins of modern policing and incarceration, the factors leading to the emergence of urban police departments, changing understandings of crime and criminals, surveillance, the wars on crime and drugs (and their racial implications), mass incarceration, deaths in custody, police corruption, police oversight, and the portrayal of law in popular culture. The course is discussion-based and includes many opportunities to engage directly with people whose lives have been impacted by crime and the criminal legal system.

79-363 The Rise of American Modern Golf, 1895 to the Present

Intermittent: 9 units
Aristocratic pastime or the people's game? Gender inclusive or overwhelmingly male? Race inclusive or overwhelmingly white? This course will examine the emergence of golf as both an amateur game and professional sport during the past century-plus. We will focus primarily on the 20th century U.S. but pay some attention to the game's earlier growth in the United Kingdom and its spread, in more recent years, throughout Europe, Asia, Latin America, and even Africa. Students will read and discuss historical, sociological, and literary texts, view documentary and feature films, and even get a taste of how to do research on golf using primary historical documents and #8212;spanning the eras from (1910s to1950s) Bobby Jones and Glenna Collett Vare to Ben Hogan, Sam Snead, Mickey Wright, and Patty Berg; and from (1960s to present) Jack Nicklaus, Arnold Palmer and Lee Trevino to Annika Sorenstam, Michelle Wie, and Lydia Ko. And Tiger Woods, too. The course will have a mid-term essay exam, a final essay exam, a mini-research assignment, and periodic oral presentations by students linked to shared readings and their individual research topics. I will lecture only occasionally; most classes will be centered on group discussion (often student-led) of assigned readings, films, and primary historical documents.

79-366 Power & Politics: A Global History of Food

Intermittent: 9 units
The course will investigate the history of food from prehistory to the present day, and will consider examples from every corner of the world. We will begin with the science of food and taste, consider origins of agriculture and industry, and the implications of society and culture.

79-367 Disastrous Encounters

Intermittent: 9 units
This course is ONLY offered at Carnegie Mellon in Qatar. Disastrous Encounters explores the complex interaction between human beings and their environment by examining incidents in which those disasters have proven destructive or fatal to humankind. By the end of the class students will be able to: Explain the scientific principles behind "natural" disasters, including cyclonic weather, global climate change, volcanoes, earthquakes, tsunamis, river flooding, famines, and diseases. Analyze to what extent a given disaster is in fact "natural" at all, but rather was either caused by or exacerbated by human actions. Draw connections between different types of disasters, recognizing that major disasters often produce predictable secondary disaster effects. Read documents critically, especially in terms of the author's agenda and the author's likely biases. Write strong analytical essays.

79-368 Un-natural Disasters: Societies and Environmental Hazards in Global Perspective

Intermittent: 6 units
In the wake of Hurricane Katrina, Neil Smith famously observed that "there is no such thing as a natural disaster." This course takes a cue from Smith by examining the social production of disasters in the past and present, from acute environmental events like typhoons and earthquakes to disasters of "slow violence" like chronic exposure to toxic pollution and food insecurity. Examining case studies from around the world, we will explore how these different forms of disaster collide with inequalities of race, class, and gender - and in the process challenge us to rethink the relationship between nature and society.

79-370 Technology in the United States

Intermittent: 9 units
This course examines the ways in which technology and society have shaped each other in the United States from the colonial era to the present. Topics include Native Americans and technologies, farming, industrialization, transportation, automobiles, aerospace, information technology, drugs, and biotechnology. Students will read a textbook, write brief essays about technologies of their choice, and discuss their essays and the text in class. The course welcomes students from any major.

79-371 African American Urban History

Intermittent: 9 units
As the ravages of the Covid-19 pandemic gradually lifts, the plight of poor and working-class people of African descent will continue to occupy a prominent place in discussions of today's urban community. Effective contemporary public policies, movement strategies, educational programs, media campaigns, and sensitive philanthropic decisions will require deeper and more thoughtful perspectives on the history of urban race and class relations in the past. Focusing on the development of African American urban history from its colonial beginnings through today's "Black Lives Matter Movement," this course will emphasize the many ways that African Americans shaped American urban life through their roles as workers, community-builders, and social justice activists. In addition to weekly classroom discussions of assigned readings, students will write a series of short essays (based upon a mix of secondary and primary sources) on selected topics/themes in the development of African American urban life, culture, and politics. This course satisfies one of the elective requirements for the African and African American Studies minor.

79-372 The Rise and Fall of Pittsburgh Steel

Intermittent: 6 units
For over 150 years, the Pittsburgh region was world-renowned for the scale and intensity of its iron and steel manufacturing complex. This mini course will trace the origins, explosive growth, stagnation and ultimate collapse of this remarkable industrial complex. Students will gain an understanding of Pittsburgh's rich industrial history - what makes it "The Steel City," understand the emergence and evolution of iron and steel making technology, appreciate the impact of Pittsburgh's iron and steel industrialization on living and working conditions for workers, and analyze the factors that drove the emergence of Pittsburgh steel then to its decline and collapse. The course is structured loosely around a set of periods in Pittsburgh's history through which key themes are drawn.

79-373 Culture and Revolution: The Socialist Experiment in Soviet Russia

Intermittent: 6 units
In 1917, revolutionaries took power in Russia to create the world's first socialist society. In a series of radical and unprecedented experiments, they attempted to remake every phase of social and cultural life, from sexual relations to art to education. How could life be lived in a new way and better way? What values should replace the old traditions based on patriarchy and class hierarchy? How could ordinary people be empowered to create a new culture? In this course, we will study the 1920s, a riotous decade of experimentation in cultural, social, and political life.

79-375 Science & Religion

Intermittent: 6 units
A widely held notion is that science and religion are perennially at "war" with one another. Debates over evolution, and more recently climate change, are cited as examples, while predictions that science will eventually make religion obsolete are at least as old as the Enlightenment. Nevertheless, both science and religion continue to thrive in the 21st century, which raises the question of whether these two ways of seeing the world might, for some people at least, be more complementary than conflictual. We'll explore the history of the relationship between science and religion and the different "ways of knowing" employed by each. Some common assumptions will be critically examined as we consider questions of fact and value, and the competency of science and religion to address the major challenges of our day.

79-377 Food, Culture, and Power: A History of Eating

Intermittent: 9 units
How can human societies ensure that 8 billion people have enough good food to eat without exploiting people or the planet? This course will start with the assumption that the answer to that question requires not only technological innovations, but also an understanding of the cultural and political dimensions of food. For the first half of the course, we will explore the history of human eating, starting in deep time and then moving toward the present, considering along the way the historical evolution of food production and consumption, paying attention to both cultural diversity and cultural exchanges of foods and cuisine. Students will pursue individual research projects focused on a topic of their choose related to major course themes during the second half of the semester. Evaluation based on in-class participation, analytical reflections on weekly readings, and the research paper.

79-378 Gender in South Asia

Intermittent: 9 units
This course introduces students to women's position and gender relations in South Asia from a historical perspective. Using gender as a lens of examining the past, we will examine how politics of race, class, caste and religion affected and continue to impact women in South Asian countries, primarily in India, Pakistan, Bangladesh and Sri Lanka. Attention is drawn to the processes by which gender is socially constructed, the prevalent forms of gender disparity and discrimination, as well as the factors of change to which these are subject. These themes are situated in the broader context of the region's history, society, and culture. We will reflect upon current debates within South Asian women's history in order to examine some of the issues and problems that arise in re-writing the past from a gendered perspective. The chronological focus of this course is on the condition of women in the subcontinent from the ancient times till the present day. Students are encouraged to make comparisons between women's position and gender relations in South Asia with the corresponding situations in their societies. Analysis and appreciation of the cross-cultural aspects of women's position and gender disparity constitute integral elements of the envisaged learning outcomes of this course. It would be of general interest to all students concerned about women's position and gender issues, as well those interested in South Asia. To help us evaluate the different historical and temporal experiences of South Asian women, this course will extensively use primary documents, secondary readings, films, and contemporary newspaper and Internet articles. Students will be required to actively engage and participate in class discussions and group debates, which will form a substantial part of individual evaluations. This course fulfills Dietrich College's "Perspectives on Justice and Injustice" general education requirement.

79-379 Extreme Ethnography

Intermittent: 9 units
Observation, participation and direct experience of "the field" are hallmarks of anthropological ways of knowing, and their representation has played a foundational role in ethnographic writing both past and present. Yet reflexive and postmodernist explorations of these topics have triggered contentious debates over the nature of anthropology as a scientific or humanistic enterprise, and over its ethical, political and epistemological value. In this seminar, we will approach such questions through an exploration of the extremes of ethnographic fieldwork and writing. We will consider such topics as: the colonial history and politics of explorers and ethnographers; liminality and the place of extreme experience and #8212;such as cultural dislocation, violence, derangement, intoxication, sex, possession, and dreaming-in fieldwork and writing; field-notes as an ethnographic genre, and their relationship to "official" published ethnography; ethnographic surrealism and surrealist ethnography; the dimensions of sensory experience (visual, auditory, olfactory, etc.) in fieldwork and ethnography; collecting and the powers of "exotic" objects; inter-subjectivity and its implications; and experimentation with alternate ethnographic forms, such as autobiography, film, diary, and poetry.

79-380 Hostile Environments: The Politics of Pollution in Global Perspective

Intermittent: 9 units
Earth is an increasingly toxic planet. Fossil-fueled industrialization, chemical engineering, and resource-intensive consumerism have generated immense wealth, but they have also left long-term, cumulative legacies of toxic pollution and ecological harm. While these legacies affect everyone, their impacts are by no means evenly distributed. In this course, we will use the tools of anthropology, political ecology, and history to examine experiences of toxic exposure in different parts of the world, including Pittsburgh. Our analyses will ask how inequalities of race, class, gender, and ability shape exposure as well as how cultural differences create divergent understandings of ecology, health, and their interrelationship. We will consider, moreover, how these disparities shape what people know about pollution and whether/how they demand accountability for it. Cases we explore will range from acute industrial disasters (and their aftermath) to the harms experienced by other-than-human beings to the gradual, often invisible exposures that affect all of us to varying degrees.

79-383 The History of Capitalism

Intermittent: 9 units
What is capitalism? How does it differ from systems that preceded it, and how did it come to revolutionize the globe? This course will cover the global development of capitalism from the 16th century to the present. We will examine the theories of Karl Marx and Adam Smith, who both attempted to theorize the new system of labor organization. We will look at how the transition from feudalism to capitalism took place, including the role of new world slavery, commodity production, dispossession of the peasantry, and changes in the household and gender relations. We will examine "globalization," the latest dynamic phase of capitalism and its impact on people. Finally, we will discuss the advent of robotization, the loss of industrial jobs, and the potential impact of casual labor, low wages, and unemployment on democracy and the rise of a technocratic elite.

79-385 Out of Africa: The Making of the African Diaspora

Intermittent: 9 units
The trans-Atlantic slave trade dispersed Africans in the New World and the Old, creating the African Diaspora. Generations of scholars have disputed whether descendants of enslaved Africans could have retained any of their African culture and/ or fully assimilated into New World societies. This course will combine a chronological, geographical, and a thematic approach to the creation of new Africa-inspired cultures in both Africa and the African Diaspora. It will explore societies in the Caribbean, the US South, Latin America, and Africa and address themes, such as Africanisms, African survivals, African retentions, Creole languages, and religion.

79-387 General Francisco Franco: Fascism and its Legacies in Spain

Intermittent: 6 units
Francisco Franco was Europe's longest-ruling dictator. He ruled over Spain from 1939 to 1975. This course will examine the social and cultural context of the rise of Fascism in Spain. We will focus especially on the colonial legacy of Spanish fascism, the violent overthrow of the democratic II Spanish Republic and Franco's seizure of power during the bloody Spanish Civil War. We will have the opportunity to learn about the international volunteers, including from the United States, who joined the fight against fascism and how the Spanish Civil War was decisive in shaping WWII. We will also discuss the decades of Franco's lengthy dictatorship, the social and cultural politics in transitioning Spain to democracy after his death and the legacy of Spanish Fascism in contemporary Spain. In addition to class lectures, students will become familiar with these themes through the reading and analysis of historical texts and memoirs, participation in a workshop with the director of the Abraham Lincoln Brigades Archives, the viewing of documentary film, and by engaging with the current volatile debates in Spain about the historical memory of fascism.

79-388 Sports in American Culture

Intermittent: 9 units
[Note: students who have taken course number 79-388, with former titles, Race, Gender, and the Politics of Sports in America since 1900 or 79-388, History of Sports in the United States, may not enroll.] In this course, we will survey the history of sport in the United States from the late nineteenth-century into the twenty-first century. While we will discuss star athletes, famous games, and popular teams, we will focus more so on evaluating the significance of sport in American history. Specifically, we will analyze sports through four themes: westernization/globalization; the emergence and development of Capitalism; industrialization and technological change; and democratization. By doing so, we will examine the changing power relationship between the athletes, owners, and consumers (fans). We will pay particular attention to athletes' changing role in American society and the public's growing expectation that these men and women speak or act on social and political issues. By semester's end, students will look beyond box scores and critically assess how sports has reflected larger trends in our society as well as its continued influence on American life.

79-391 Nations and Nationalisms in South Asia

Intermittent: 9 units
This course examines the role which nationalism has played in the formation and political development of the nations and states of South Asia. It, therefore, examines nationalist forces in anti-colonial struggles, in post-colonial state formation and in contemporary political developments. It will be of relevance to students with an interest in political developments in Asia, with particular reference to forms of nationalism and nation-building.

79-392 Europe and the Islamic World

Intermittent: 9 units
Europe and the Islamic World explores the complex relationship between (Christian) Europe and Islamic civilization, from the conquest of the Byzantine Levant to modern-day Islamic immigration into Europe. The course will focus on a few landmark events in European/Islamic relations, such as the crusades, as well as various intellectual models describing European/Islamic relations over time. The course will also focus on developing research, writing, and documentary analysis skills relevant to the study of history.

79-393 Institutions of the Roman Church

Intermittent: 9 units
This course is only offered at Carnegie Mellon's campus in Qatar. This course will explore the history of the Catholic Church, with a particular focus on the church as an evolving European institution. Although we will have to deal with theological arguments at times, abstract theology will not be the focus of the course. Instead, the course will be centered on two main questions. First, how did the Catholic Church manage to persist, for nearly two millennium, as a stable institutional entity within an ever-changing European milieu? Secondly, to what degree did the Catholic Church influence and/or reflect developments within Western European culture?

79-394 Exploring History through Geography

Intermittent: 6 units
For studying the past, space can be as important as time. Digital mapping and GeoLocation technologies influence our everyday interactions and perceptions of the world around us. Historians are thinking about how these technologies can change their fields of study, too. Through the "spatial turn" in the Humanities and Social Sciences, historians are using spatial experience to think more deeply about the meaning of place and space. Visualizing spatial relationships via new technologies can offer meaningful new ways to approach historical questions. This course will consider viewpoints from the discipline of Geography and explore the impact of new methods in the Digital Humanities, including the impact of digital tools such as Geographic Information Systems (GIS).

79-395 The Arts in Pittsburgh

Intermittent: 9 units
This course will examine the arts in Pittsburgh, both historically and in the present. We will pay special attention to musical events and art exhibits scheduled by the city's concert halls and art museums, several of which we will attend as a group. Our "curriculum," in other words, will derive partly from the city's artistic presentations themselves, which will provide a springboard for reading assignments, discussions, a small research project (which I will work out individually with each of you), and one or two essay exams. The History Department will pay for students' admission to all museums. However, students will be charged a supplemental fee (at discounted prices) to help subsidize the considerable expense of purchasing tickets for performances by the Pittsburgh Symphony, Pittsburgh Opera, Pittsburgh Ballet, Chamber Music Pittsburgh, or other musical organizations. Attendance at all musical events and art exhibits is required.

79-396 Music, Art, and Society in 19th and 20th Century Europe and the U.S.

Intermittent: 9 units
This course will explore the interrelations between society, classical and popular music, and art in the nineteenth and early twentieth centuries in Europe and the United States. We will examine the importance of different musical forms in the life of society and how music and art reflected changing political and cultural consciousness in several national settings. We will also analyze trends in artistic expression by examining the collections and historical development of several notable European and American art museums. The "curriculum" in other words, will derive from the artistic presentations themselves and #8212; symphonies, operas, chamber music, ballet, and art exhibits and #8212; which will provide a springboard for reading assignments, discussions, a personal artistic journal, and written assignments that will help you synthesize your diverse forays into the history of music and art. In addition to visiting Carnegie Museums of Pittsburgh, students will be taking to the performances of the CMU School of Drama, Pittsburgh Symphony, Pittsburgh Opera, chamber music concerts, performances of the Pittsburgh Cultural Trust. A supplemental fee of $170 will be charged to help subsidize the considerable expense of purchasing tickets for concerts and performances.

79-400 Global Studies Research Seminar

Fall: 12 units
This research seminar is the capstone course for Global Studies majors. The course is designed to give you a chance to define and carry out a research project of personal interest. The first few weeks of the course will be devoted to developing a research topic and locating sources. We will then work on how to interpret and synthesize sources into a coherent and compelling thesis before you begin drafting your paper. Your research may be based on in-depth reading of a body of scholarly work, field notes from ethnographic observations, archival research, analysis of literary or visual media, or some combination of these sources. Incorporation of some non-English language sources is strongly encouraged where possible. Independent work, self-initiative, participation in discussion, and peer evaluations are required. There are several interim deadlines that will be strictly enforced in order to ensure successful completion of the course.

79-420 Historical Research Seminar

Fall: 12 units
The purpose of this research seminar is to help students conceptualize, design, organize, and execute a substantial research project that embodies and extends the knowledge and skill set they have been developing as History majors at Carnegie Mellon. The identification, collection and interpretation of relevant primary source data are integral parts of this intellectual task. Students will hone written and oral presentation skills, deepen their command of research methodologies and strategies, and sharpen their abilities as a constructive critic of others' research. The seminar seeks to develop these intellectual skills through a combination of in-class, student-led discussions of everyone's research-in-progress, and regular individual consultations with the instructor.
Prerequisite: 79-200 Min. grade C

79-449 EHPP Capstone Course

Fall: 12 units
In this Fall 2023 capstone course, Ethics, History, and Public Policy majors will carry out a collaborative or individual research project that examines a compelling current policy issue that can be illuminated with historical research and philosophical and policy analysis. Students will develop an original research report based on both archival and contemporary data and present their results in a public forum at the end of the semester. Please note: this semester we are experimenting with a more flexible set of research options for EHPP students, rather than a single project topic that all students are required to work on. Collaborative projects in groups of 2-3 students are encouraged, but individual projects that integrate historical, ethical, and policy perspectives are permissible too.

79-452 Women's Bodies and Cultural Politics

Intermittent: 3 units
This course explores the fraught, often shameful, often triumphant, and sometimes deadly cultural ideas and expectations around cis-gendered women's bodies. We want to explore what the stories we attach to female bodies mean, who they serve, and whether they are changeable. Are our ideas derived from science or culture? And why might it matter? Built from a popular U.S. based-course on the Pittsburgh campus, this course aims to bring feminist analysis around American cis-gendered women's bodies to an audience in Doha, and asks you to build, through class discussion and assignments, your own analyses of how these ideas and concepts work in your own culture. You will no doubt come to different conclusions, which is the goal: for you to think independently and analytically, to build your own ideas. The course is organized topically. We will learn some reproductive anatomy and biology (including the menstrual cycle), and also survey reproductive politics, sexuality, gender-based violence, and a topic of your choice. It will be heavily discussion based. No prerequisites or prior experience with this material needed and #8212;open to all.

79-453 Global Water and Development

Intermittent: 3 units
Water is necessary for all forms of life on Earth. An estimated 1 billion humans do not have satisfactory drinking water; an estimated 2 billion do not have access to adequate sanitation facilities for human health, safety, and dignity. For more than a hundred years, to address social inequalities in access to water, international organizations and scholars have created their own theories and ideas about providing water. This international community points out the social and cultural implications of technical provision of water resources. These debates about "development" showcase diverse theories, recommendations, and contradictions. The purpose of this course is to introduce students to critical studies of water and development. We will consider complex stories of social change, including unintended consequences; human and environmental impacts; and debates among experts.

79-454 The TransOceanic Railway

Intermittent: 3 units
This course is an introduction to railway restructuring and privatization, which arguably began in exactly 1990 with the privatization of Argentina's railways. The Argentine model has been replicated on other continents and in many settings and is modeled on the successful USA model of private ownership and operation of freight rail, which is generally considered a model for the world. Conversely, passenger rail in the USA almost disappeared while in the UK it has enjoyed a spectacular run with a doubling of ridership since the privatization of its railways in roughly the same era, i.e., the Thatcher years. The UK's model has been replicated in various forms throughout Europe and beyond.

79-465 The Arts in Qatar

Intermittent: 9 units
This course will examine the arts in Qatar, both historically and in the present. We will focus especially on art exhibits and musical events scheduled by the city's museums and concert halls during the Spring 2020 semester. The "curriculum" will derive from the artistic presentations themselves, which will provide a springboard for reading assignments and research papers in the history of music and art. We will also examine the historical development of cultural institutions in Qatar.

79-470 Simulating Conflict Resolution

Intermittent: 3 units
This course is only offered at Carnegie Mellon's campus in Qatar. This pass-fail, 3-credit course for the Qatar campus is designed to prepare students for a capstone event: an international conflict resolution exercise, to be held in the 2018 Spring semester, that simulates a current Middle Eastern crisis. The course will consist of two parts. First, students will meet weekly with an instructor for 1 hour/week to discuss the historical and modern Middle East, so that they will be prepared to participate meaningfully in the simulation. For these classes, students will be expected to complete and discuss readings prepared by the instructor. Secondly, students will participate in the simulation exercise in late spring, taking the role of one of the Middle Eastern actors (these will be decided ahead of time) and role-playing their nation's response to the specific crisis scenario. Finally, after the simulation, students will submit to the instructor a reflection paper on what they learned from participating in the event. Suggested pre- or co-req: Conflict Resolution (80-242 or 70-321).

79-491 Independent Study

Intermittent
An Independent Study is meant for students with a special interest in an area not covered by a formal history course. Readings and other work are negotiated between the student and an individual faculty member.

79-505 Internship: Social & Political History

All Semesters
The Social and amp; Political History program strongly encourages students to locate internship opportunities in Pittsburgh or elsewhere that complement their historical interests (as, for example, in a museum or historical society) or in areas of policy research that complement their historical interests (as, for example, in a government agency or non-profit organization). To earn academic credit for their internship, students will be required to maintain a weekly journal; write a short critical reflection on how the internship connects to their academic interests; and share their experience with other Social and amp; Political History majors. The Academic Advisor will assist students with matching their interests to local organizations. SPH students can earn up to 9 units in each internship. Please note, however, that internship credits (students may complete up to three internships) do not count toward fulfillment of course requirements for the SPH major (though the units do count toward graduation).

79-506 Global Studies Internship

Fall and Spring
This course provides Global Studies majors with a chance to explore global connections in Pittsburgh. Majors, working in close consultation with the Global Studies director and advisor, will arrange an internship with a non-governmental organization (usually in Pittsburgh) whose mission has a global reach. This could include an organization that supports projects in other countries, works with immigrants in the Pittsburgh area, or participates in international policy making/governance. We strongly encourage students to seek out opportunities that require use of a second language. Students will be required to maintain a weekly journal; write a short critical reflection on how the internship connects to academic work; and share their experience with other Global Studies majors. Global Studies advisor and director will assist students with matching their interests to local organizations and identifying an on-site supervisor available to collaborate in the ongoing and final evaluation of the student's work.
Prerequisite: Students must be Global Studies majors and obtain permission for the proposed internship from the Global Studies advisor.

79-510 Global Studies Guided Reading

All Semesters: 3 units
Global Studies Guided Reading (Fall 2023: The Environment and Climate Change) The main goal of this seminar is to encourage students to engage deeply with four books on a distinct topic, and discuss them under the guidance of the professor. You could think of this seminar as a more academically-oriented monthly book club! The small size of the seminar allows for a deep immersion in the readings, and for the development of critical thinking among students. The four books are selected by the professor, and the selection is based on several criteria, including the books' impact, current relevance, regional foci, as well as diversity and inclusivity reflected by the authors' different social, racial, and geographical backgrounds. The topics of the seminars each semester will vary, but all will have global relevance. (For instance, the Fall '22 seminar will focus on the environment and climate change, and the Spring '23 seminar will deal with the topic of cultural and historical memory). Important: In order to encourage all of the students' constant participation and their deep engagement with the books, as well as foster a sense of intellectual community, this seminar will be strategically small. For these reasons, only the GS majors will be allowed to register for this monthly guided reading. Meets monthly on Fridays.

The Major in Information Systems

Joe Mertz, Faculty Director

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Did you enjoy computer science or more technical courses in high school, but are mostly interested in the practical and social applications of technology? Do you have a passion for business and want to use advanced technology to change how companies work? Do you want to learn how data and technology can be harnessed for social good?

Carnegie Mellon University's **Information Systems (IS) program,** a joint degree program between the Heinz College and Dietrich College of Humanities and Social Sciences is strongly technical, drawing from Carnegie Mellon's leadership in computer science, human-centered design, business management and software engineering. It is deeply rooted in the humanities and social sciences, allowing students the lifelong benefits of a rich liberal arts education. And it provides pathways for students to find their own Information Systems niche through advanced study and research with leading researchers. As a result, our graduates are uniquely positioned to envision and drive the positive organizational change that technology makes possible.

Artificial intelligence. Machine learning. Deep learning. Big data. Social networks. Neural networks. Robotics. Automated voice assistants. Blockchain. Driverless vehicles.

Do you want to use technologies like these to benefit companies, governments, and society? CMU offers the world's best undergraduate IS program and will help you do just that. In fact, many of the world-changing technologies listed above were invented here on campus—there is no better place to become a tech leader than CMU.

The field of Information Systems involves the effective design, delivery, and use of information and communications technologies to solve problems for companies, governments, and society. Equally, it is about understanding and measuring the impacts of these technologies on people and communities so they can be deployed ethically.

As an IS student, you will build a solid foundation in computing, communications, and software development. You will also study social sciences and organizational theory to develop "big picture" critical thinking and understand the human impacts of technological change. This blend prepares you to take a leading role in our digital future. The flexible nature of the program encourages students to explore their own interests through program electives, study in a contemporary concentration or through optional second majors and minors.

IS students are well prepared to pursue graduate work in a wide range of fields. For students interested in master's degree-level graduate work at Carnegie Mellon, there are many possibilities, including accelerated Masters degree programs in Information Systems Management, Human Computer Interaction, Information Security Policy and Management, Engineering Technology and Innovation Management, and Business Administration.

IS graduates continue to be in high demand in the information-age workplace. There has been a strong job market for IS students in recent years, and national trends indicate that this is likely to continue. IS majors often take jobs in consulting companies, major software firms, large corporations, and start-up companies. Internship opportunities closely parallel the job market.

In addition to General Education Requirements and basic prerequisites in Mathematics and Computer Science, The IS program curriculum includes:

- A broad grounding in humanities and social sciences to promote self-directed learning, critical thinking, and interdisciplinary problem-solving.
- An Information Systems Core to provide the technology, project management, and business-facing skills needed to design and build effective real-world systems solutions.
- An Information Systems Breadth focused on professional communications, quantitative analysis, and how technology functions in society.
- A Concentration that gives you the flexibility and agency to gain expertise in a supporting area and define your own niche in IS.

The IS major is the perfect place for you if you are passionate about using technology for positive gains across society, both economic and humanistic.

IS Commitment on Diversity & Inclusion:

Diversity, equity and inclusion are core values of the Information Systems Program. We strive to foster a community that promotes inclusiveness and a positive sense of belonging among all students within the program. Together, we value and celebrate the unique identities of our students and aim to create a culture where they feel empowered to share their experiences and ideas, and engage in meaningful academic, leadership, and social opportunities. We aim to elevate cultural awareness through education, programming, and an environment that embraces differences.

Study Abroad Options in Information Systems:

Given the importance of globalization, we encourage students to consider expanding their international experience by spending a semester studying abroad. The IS program is very flexible in allowing students to pursue these opportunities. With careful planning, study abroad is possible during most semesters. Students interested in study abroad should talk with the IS Academic Advisor to help plan an appropriate course of study. With prior approval, study abroad courses may be applied to major requirements.

Information Systems as Additional Major or Minor:

Information Systems is not available as either an additional major or minor.

Curriculum

The Information Systems major is offered only as a Bachelor of Science (B.S.) degree. In addition to major requirements outlined below, all Information Systems students must fulfill the General Education requirements for the Dietrich College of Humanities and Social Sciences. A total of 360 units is required for the degree.

Requirements are subject to revision. Advisor approval is required for each student's major curriculum plan. Any proposed course substitutions to courses required for the IS major must be approved in advance by the IS Academic Advisor.

Technical Core (Prerequisites)

Information Systems requires completion of prerequisite courses in Mathematics and Computer Science. All prerequisites must be successfully completed prior to the start of Fall semester, junior year.

Mathematics

Complete one of the following math courses:

		Units
21-112	Calculus II (pre-requisite of 21-111)	10
21-120	Differential and Integral Calculus	10
21-127	Concepts of Mathematics	12
21-240	Matrix Algebra with Applications	10
80-210	Logic and Proofs	9

Computer Science

Three Computer Science courses are required. To maintain normal progress toward the Information Systems degree, students must complete 15-121 Introduction to Data Structures prior to the start of Spring Semester, sophomore year.

Students entering the program as freshmen will have the option to complete a Computer Science Placement Test. Depending on appropriate Advanced Placement credit and/or results of the Computer Science Placement Test, entering students may place directly into 15-112 (http://coursecatalog.web.cmu.edu/search/?P=15-112) or 15-121 (http://coursecatalog.web.cmu.edu/search/?P=15-121). 15-110 (http://coursecatalog.web.cmu.edu/search/?P=15-110) is taken as the first Computer Science prerequisite unless a student places directly into 15-112 (http://coursecatalog.web.cmu.edu/search/?P=15-112) or 15-121 (http://coursecatalog.web.cmu.edu/search/?P=15-121). Students that do not gain a placement into 15-112 (http://coursecatalog.web.cmu.edu/search/?P=15-112) or 15-121 (http://coursecatalog.web.cmu.edu/search/?P=15-121) must begin the sequence with 15-110 (http://coursecatalog.web.cmu.edu/search/?P=15-110) and must complete it with a grade of D or above prior to entering 15-112 (http://coursecatalog.web.cmu.edu/search/?P=15-112).

		Units
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
15-121	Introduction to Data Structures	10

Note: Students cannot receive credit for both 15-104 Introduction to Computing for Creative Practice and 15-110 Principles of Computing. Students may also take 15-122 (http://coursecatalog.web.cmu.edu/search/?P=15-122) Principles of Imperative Computation in place of 15-121 (http://coursecatalog.web.cmu.edu/search/?P=15-121) Introduction to Data Structures but should first consult with their academic advisor prior to doing so.

Information Systems Core

In the Information Systems Core, students will learn the basic skills necessary to analyze, design, implement, and test high-quality, cost effective information systems. The Information Systems Core consists of seven courses (not including 67-100 and 67-200).

Complete all of these courses:

		Units
67-100	Information Systems First Year Colloquium	1
67-200	Information Systems Research Colloquium	1
67-250	The Information Systems Milieux (Spring Semester Only)	9
67-262	Database Design and Development (Fall Semester Only)	9
67-272	Application Design and Development (Spring Semester Only)	12
67-373	Information Systems Consulting Project (Spring Semester Only)	12
17-313	Foundations of Software Engineering	12
95-422	Managing Digital Transformation	9

Complete one of these three courses:

		Units
05-391	Designing Human Centered Software	12
05-410	User-Centered Research and Evaluation Not open to first-year students.	12
05-452	Service Design	12

Information Systems Breadth

In the Information Systems Breadth, students will study key areas fundamental to understanding and solving problems in information systems. At least one course is required from each of the following categories:

Professional Communications

Information systems professionals communicate with a wide range of people in most organizations and often facilitate communications between diverse groups of stakeholders. Consequently, the most successful professionals typically are those with strong communication skills. These courses help students see that the structure and presentation of information affects how well (and how easily) it can be understood and used.

Complete one of the following courses:

		Units
05-317	Design of Artificial Intelligence Products	12
36-315	Statistical Graphics and Visualization	9
51-261	Communication & Digital Design Fundamentals	9
or 51-262	Design Center: Communication and Digital Design Fundamentals	
67-265	Design Fundamentals: Shaping Interactions and Experiences	9
67-336	Building Data Visualizations in to Information Systems	9
67-338	Information & Grid Design	9
70-321	Negotiation and Conflict Resolution	9
70-340	Business Communications	9
70-342	Managing Across Cultures	9
70-350	Acting for Business	9
76-270	Writing for the Professions	9
84-250	Writing for Political Science and Policy	9
88-230	Human Intelligence and Human Stupidity	9
88-231	Thinking in Person vs. Thinking Online	9
88-341	Team Dynamics and Leadership	9
or 70-341	Team Dynamics and Leadership	

Quantitative Analysis and Research Methods

This area focuses on decision making and data analysis — essential to development of useful information systems. This area exposes students to analytic methods in the social sciences and quantitative methods for approaching complex methods.

Complete one of the following courses:

		Units
21-257	Models and Methods for Optimization	9
21-325	Probability	9
36-202	Methods for Statistics & Data Science	9
36-219	Probability Theory and Random Processes	9
36-225	Introduction to Probability Theory	9
36-235	Probability and Statistical Inference I	9
36-303	Sampling, Survey and Society	9
36-309	Experimental Design for Behavioral & Social Sciences	9
36-315	Statistical Graphics and Visualization	9
36-350	Statistical Computing	9
36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9
67-285	Across the Universe from Intelligent Agents to Users	9
67-364	Practical Data Science	9
73-265	Economics and Data Science	9
80-305	Game Theory	9
80-306	Decision Theory	9
88-223	Decision Analysis	12
88-251	Empirical Research Methods	9
88-252	Causal Inference: from Data to Decisions	9
88-275	Bubbles: Data Science for Human Minds	9
88-300	Programming and Data Analysis for Social Scientists	9
94-216	Introduction to Decision Analytics and Systems	6

Innovation and Entrepreneurship

The focus of this area is to apply disciplined techniques to generate ideas that have value in a market, and bring them through design, feasibility testing, and frequent revision, towards a potential launch. Students must complete 67-272 Application Design & Development in order to fulfill one of the courses below towards their Innovation and Entrepreneurship requirement.

Complete one of the following courses:

		Units
05-470	Digital Service Innovation	12
17-356	Software Engineering for Startups	12
67-443	Mobile Application Design and Development	12
94-491	Lean Innovation Lab	12

Information systems concentration

The study of Information Systems can take many paths; **Concentrations** allow students to find the path that best suits their plans and aspirations. They also allow students to establish relationships with leading researchers in their area of interest. It is strongly recommended to determine your concentration requirement by the end of the sophomore year to ensure timely completion by the conclusion of the fourth year.

IS Concentrations include:

- Data Analytics
- Health Information Systems
- Technology & Arts Enterprises
- Technology & International Development
- User Experience (UX) Design

Alternatively, students may choose from an approved list of minors or additional majors, including those offered through the Integrative Design, Arts, and Technology (IDeATe) (https://ideate.cmu.edu/undergraduate-programs/) initiative that blend information systems and the arts as only Carnegie Mellon University can.

Additional Majors:

- Artificial Intelligence (https://www.cs.cmu.edu/bs-in-artificial-intelligence/additional-major/)
- Behavioral Economics (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/departmentofsocialanddecisionsciences/)
- Business Administration (http://coursecatalog.web.cmu.edu/schools-colleges/tepper/undergraduatebusinessadministrationprogram/)
- Cognitive Science (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/departmentofpsychology/#cognitive_sciencetext)
- Computational Biology (https://cbd.cmu.edu/education/undergraduate/minor-in-computational-biology.html)
- Computational Finance (http://coursecatalog.web.cmu.edu/intercollegeprograms/#majorminorincomputationalfinancetextcontainer)
- Computer Science (http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/undergraduatecomputerscience/#csadditionalmajorminortext)
- Decision Science (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/departmentofsocialanddecisionsciences/#minorstextcontainer)
- Economics (http://coursecatalog.web.cmu.edu/schools-colleges/tepper/undergraduateeconomicsprogram/#dualdegreeadditionalmajortext)
- Economics & Statistics (https://www.cmu.edu/dietrich/statistics-datascience/academics/undergraduate/majors/econstat.html)
- Engineering & Public Policy (http://coursecatalog.web.cmu.edu/schools-colleges/collegeofengineering/departmentofengineeringandpublicpolicy/#doublemajorcurriculumtext)
- Human-Computer Interaction (http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/humancomputerinteractionprogram/#humancomputerinteractionadditionalmajortextcontainer/#humancomputerinteractionminortext)
- Linguistics (https://www.cmu.edu/dietrich/linguistics/undergraduate/major.html)
- Policy & Management (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/departmentofsocialanddecisionsciences/#minorinpolicyandmanagementtextcontainer)
- Robotics (http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/addlmajorsminors/#roboticsadditionalmajorminortext)
- Statistics (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/departmentofstatistics/#minortext)
- Statistics and Machine Learning (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/departmentofstatistics/#statsmltext)

Approved minors:

- Artificial Intelligence (https://www.cs.cmu.edu/bs-in-artificial-intelligence/minor/)
- Behavioral Economics (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/departmentofsocialanddecisionsciences/)
- Business Analytics & Optimization (http://coursecatalog.web.cmu.edu/schools-colleges/tepper/undergraduatebusinessadministrationprogram/#minorinbusinessanalyticsoptimizationtext)
- Computational Biology (https://cbd.cmu.edu/education/undergraduate/minor-in-computational-biology.html)
- Computational Finance (http://coursecatalog.web.cmu.edu/intercollegeprograms/#majorminorincomputationalfinancetextcontainer)
- Computer Science (http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/undergraduatecomputerscience/#computerscienceminortextcontainer/#csadditionalmajorminortext)
- Cybersecurity & International Conflict (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/instituteforpoliticsandstrategy/#minorincybersecurityandinternationalconflicttext)
- Decision Analytics & Systems (https://www.heinz.cmu.edu/programs/decision-analytics-and-systems/)
- Decision Science (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/departmentofsocialanddecisionsciences/#minorstextcontainer)
- Economics (http://coursecatalog.web.cmu.edu/schools-colleges/tepper/undergraduateeconomicsprogram/#dualdegreeadditionalmajortext)
- Engineering Studies (p. 192)
- Financial Management (http://coursecatalog.web.cmu.edu/schools-colleges/tepper/undergraduatebusinessadministrationprogram/)
- Human-Computer Interaction (http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/humancomputerinteractionprogram/#humancomputerinteractionminortext)
- Humanities Analytics (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/departmentofenglish/#minorstext)
- IDeATe: (https://ideate.cmu.edu/undergraduate-programs/game-design/)Animation & Special Effects (https://ideate.cmu.edu/undergraduate-programs/animation-special-effects/)
- IDeATe: (https://ideate.cmu.edu/undergraduate-programs/game-design/)Design for Learning (https://ideate.cmu.edu/undergraduate-programs/design-for-learning/)
- IDeATe: Game Design (https://ideate.cmu.edu/undergraduate-programs/game-design/)
- IDeATe: Immersive Technologies in Arts & Culture (https://ideate.cmu.edu/undergraduate-programs/immersive-technologies-in-arts-culture/)

- IDeATe: (https://ideate.cmu.edu/undergraduate-programs/game-design/)Innovation & Entrepreneurship (https://ideate.cmu.edu/undergraduate-programs/innovation-and-entrepreneurship/)
- IDeATe: (https://ideate.cmu.edu/undergraduate-programs/game-design/)Intelligent Environments (https://ideate.cmu.edu/undergraduate-programs/intelligent-environments/)
- IDeATe: (https://ideate.cmu.edu/undergraduate-programs/game-design/)Physical Computing (https://ideate.cmu.edu/undergraduate-programs/physical-computing/)
- IDeATe: (https://ideate.cmu.edu/undergraduate-programs/game-design/)Media Design (https://ideate.cmu.edu/undergraduate-programs/media-design/)
- IDeATe: (https://ideate.cmu.edu/undergraduate-programs/game-design/)Sonic Arts (https://ideate.cmu.edu/undergraduate-programs/sonic-arts/)
- IDeATe: (https://ideate.cmu.edu/undergraduate-programs/game-design/)Soft Technologies (https://ideate.cmu.edu/undergraduate-programs/soft-technologies/)
- Information Security, Privacy, and Policy (http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/addlmajorsminors/#informationsecurityprivacyandpolicyminortextcontainer)
- Language Technologies (http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/addlmajorsminors/#languagetechnologiesminortextcontainer)
- Linguistics (https://www.cmu.edu/dietrich/linguistics/undergraduate/minor.html)
- Machine Learning (http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/addlmajorsminors/#machinelearningminortextcontainer)
- Neural Computation (http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/addlmajorsminors/#neuralcomputationminortextcontainer)
- Operations & Supply Chain Management (http://coursecatalog.web.cmu.edu/schools-colleges/tepper/undergraduatebusinessadministrationprogram/#minorinoperationsandsupplychainmanagementtext)
- Political Science, Security, and Technology (https://www.cmu.edu/cmist/academics/undergraduate-programs/minor-in-political-science-security-technology.html)
- Product Management (http://coursecatalog.web.cmu.edu/schools-colleges/tepper/undergraduatebusinessadministrationprogram/#productmanagement)
- Science, Technology & Society (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/interdepartmentalminors/#sciencetechnologyandsocietytext)
- Software Engineering (http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/addlmajorsminors/#softwareengineeringminortextcontainer)
- Statistics (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/departmentofstatistics/#minortext)
- Tech Entrepreneurship (requires semester abroad at CMU Qatar, minor only) (https://www.cmu.edu/information-systems/sdm-tech-entrepreneurship-minor/)
- Technology & Policy (http://coursecatalog.web.cmu.edu/schools-colleges/collegeofengineering/minorsfornonengineeringstudents/#text)

Sample Curriculum

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
67-100 Information Systems First Year Colloquium	67-250 The Information Systems Milieux	67-200 Information Systems Research Colloquium	67-272 Application Design and Development
15-110 Principles of Computing	15-112 Fundamentals of Programming and Computer Science	67-262 Database Design and Development	Quantitative Analysis Requirement
36-200 Reasoning with Data	Grand Challenge Seminar	15-121 Introduction to Data Structures	General Education Course
76-101 Interpretation and Argument or other approved first-year writing options	General Education Course	Professional Communications Requirement	Elective Course
Math Requirement	General Education Course	General Education Course	Elective Course
Elective Course		Elective Course	
99-101 Core@CMU			

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
17-313 Foundations of Software Engineering	67-373 Information Systems Consulting Project	95-422 Managing Digital Transformation	Concentration Course
Concentration Course	Concentration Course	Concentration Course	General Education Course
HCI Requirement	General Education Course	Innovation & Entrepreneurship Requirement	Elective Course
General Education Course	Elective Course	General Education Course	Elective Course
Elective Course	Elective Course	Elective Course	Elective Course

Academic Policies

Transfer into Information Systems

Applications will be considered based on the following criteria:

- Completion of 15-112 Fundamentals of Programming and Computer Science with final grade of 'B' is required; a final grade of 'A' is preferred
- Completion of 15-121 or 15-122 is preferred, with a grade of 'B' or higher
- Strong record of academic performance at Carnegie Mellon (minimum QPA of 3.5 required)
- Personal statement (1-2 pages single spaced) on the following topic: *In your personal statement, please describe how your academic and career goals relate to the Information Systems Program. Please discuss your previous experiences that have led you to pursue the IS major, and how IS aligns with your future goals and aspirations. You may also discuss any other IS related experiences (e.g. internships, course projects, research, co-curricular experiences, etc.) or relevant coursework.*
- Interview with an IS Academic Advisor: IS advisor appointments should be made with the appropriate advisor (based on student last name) via the links on the advising page (https://cms-staging.andrew.cmu.edu/information-systems-4/current-students/advising.html) and should be completed by the deadline set forth for the current semester.
- Sample course plan through graduation (4th semester applicants only) When making your plan, we strongly recommend utilizing Stellic. The only Dietrich General Education course that will be waived is the Grand Challenge Seminar.

Application (https://forms.gle/9XFDdy31avh8LW326/) materials must be submitted no later than the last day of classes of the fall or spring semester. Students admitted into the IS Program will be officially declared in the semester following their application to the IS Program. If admitted, students will be declared as an IS major prior to the start of the following semester. All internal transfer students will be required to take 67-200: IS Research Colloquium during the first fall semester of their IS enrollment.

Students interested in applying for transfer to the Information Systems major should contact an IS Academic Advisor (https://cms-staging.andrew.cmu.edu/information-systems-4/current-students/advising.html) for information regarding availability, application procedures, and deadlines.

Double Counting of Courses

"Double Counting" refers to instances when a course taken to fulfill one requirement counts simultaneously toward a requirement in another major or minor program. Double Counting is permitted in the Dietrich College on a very limited basis. Information Systems students may double count no more than two courses towards an additional major/minor. There is no restriction on double counting for courses satisfying the Dietrich College General Education requirements and IS Prerequisite courses. Students must also adhere to any policy restrictions on double counting enforced by the academic department of the student's additional major or minor.

Course Repeats

Per university policy, when a course is repeated, all grades will be recorded on the official academic transcript and will be calculated in the student's QPA. This is the case regardless if the first grade for the course is a passing or failing grade.

Undergraduate students who wish to repeat a course already passed must obtain approval from the student's Dean or Department Head. When a student takes a course they already passed, only one set of units will count towards graduation requirements.

Faculty

MOHAMMAD AAZAM, Assistant Teaching Professor – Ph.D., Kyung Hee University ; Carnegie Mellon, 2022–

CHADI AOUN, CMU-Qatar Information Systems Area Head & Teaching Professor – Ph.D., Univeristy of New South Wales; Carnegie Mellon, 2015–

HOUDA BOUAMOR , Associate Teaching Professor – Ph.D., Paris-Sud University ; Carnegie Mellon, 2012–

ANIS CHARFI, Associate Teaching Professor – Dr.Ing., Technische Universitat Darmstadt; Carnegie Mellon, 2015–

SUSAN HAGAN, Associate Teaching Professor Emeritus – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2004–

C.F. LARRY HEIMANN, Teaching Professor – Ph.D., Washington University (St. Louis); Carnegie Mellon, 1998–

SHIHONG HUANG, Teaching Professor – Ph.D., University of California, Riverside; Carnegie Mellon, 2023–

NAAMA ILANY-TZUR, Assistant Teaching Professor – Ph.D , Ben-Gurion University of the Negev; Carnegie Mellon, 2023–

DIVAKARAN LIGINLAL, Teaching Professor – Ph.D., University of Arizona - Tucson; Carnegie Mellon, 2009–

SELMA LIMAM MANSAR, Teaching Professor Emeritus – Ph.D., National Polytechnic Institute of Grenoble; Carnegie Mellon, 2007–

JOSEPH S. MERTZ, Program Director & Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1997–

MANORANJAN MOHANTY, Assistant Teaching Professor – Ph.D.,Carnegie Mellon, 2024–

SARA MOUSSAWI, Associate Teaching Professor – Ph.D. , City University of New York; Carnegie Mellon, 2016-–

DANIEL PHELPS, Associate Teaching Professor Emeritus – Ph.D., Florida State University; Carnegie Mellon, 2007–

JULIA POEPPING, Director of Partnership Development – Masters, University of Pittsburgh ; Carnegie Mellon, 2019–

JERIA QUESENBERRY, Teaching Professor & Dietrich College Associate Dean of Faculty – Ph.D., Pennsylvania State University; Carnegie Mellon, 2007–

RAJA SOORIAMURTHI, Teaching Professor – Ph.D., Indiana University; Carnegie Mellon, 2007–

XIAOYING TU, Assistant Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2020–

SAVANID (NUI) VATANASAKDAKUL, Associate Teaching Professor – PhD., University of New South Wales; Carnegie Mellon, 2018–

RANDY S. WEINBERG, Teaching Professor Emeritus – Ph.D., University of Minnesota; Carnegie Mellon, 1998–

The Major in Information Systems Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

67-100 Information Systems First Year Colloquium

Fall: 1 unit
This IS Colloquium will provide a broad introduction to the Information Systems Program, an exciting program newly joint between Carnegie Mellon's Dietrich College and Heinz College. The IS Colloquium is open only to first-year IS students and is led by an IS academic advisor who facilitates discussions on the field of IS, the program curriculum, and careers, in addition to co-curricular experiences such as internships and study abroad. Because the flexible nature of the IS program encourages students to explore their own interests, we place an emphasis on highlighting a variety of areas within the field of IS. Guest lecturers will include leaders in IS research including Dietrich and Heinz faculty and IS alumni. Additional speakers include the IS career consultant and various campus representatives. Discussions will include students' progress in their first semester, as well as guidance in course planning, creating student Spring semester class schedules, and their overall four-year plan.

67-135 Discover, organize, and synthesize: Building your research toolkit beyond Google

Intermittent: 3 units
The world of academic research literature is growing exponentially across all disciplines, leaving researchers and decision-makers with a conundrum: how do we effectively identify research gaps and how do we make sense of what we already know, given the millions of research articles published every year? This micro course will equip students with techniques and tools for a systematic approach to finding, assessing and making sense of research knowledge, applying principles from well-established synthesis methods. Students will explore the scholarly research in interdisciplinary topics and topics in their own subject areas. Students will gain skills they can apply to any research course, and will be able to use these techniques in their future careers as practitioners for making sound, evidence- and research-based decisions.

67-200 Information Systems Research Colloquium

Fall: 1 unit
The Information Systems Research Colloquium will educate students on research opportunities both in IS and beyond. By the end of the course, students should be able to: · Articulate what undergraduate research looks like at Carnegie Mellon University, and particularly identify the breadth of research opportunities in the field of Information Systems · Demonstrate how to communicate with faculty whose work aligns with individual interests · Describe several career and continuing education opportunities for Information Systems students The Information Systems Research Colloquium is open only to sophomore IS student as well as recent transfer students and is led by an IS academic advisor who facilitates discussions on the various research topics both through IS and other campus constituents.

67-204 Blockchains in Industry

All Semesters: 3 units
Industry experts characterize blockchains as breakthrough technology that has the same transformative power as that of the Internet. Blockchains have the potential to solve a variety of problems that benefit from a decentralized model of trust. This course will help students understand fundamental blockchain concepts and develop industry case studies of blockchain applications to finance, insurance, energy, healthcare, real estate, etc.

67-206 Technology Outreach and Engagement in the Pittsburgh Community

Fall and Spring: 6 units
This course is designed to provide an experiential learning opportunity to CMU students. In this course students will develop material to conduct outreach with children in grades K-12. CMU students will engage with the community, have conversations with community partners and educators, and demonstrate knowledge of civic engagement, cultural identity and diversity / inclusion. Experiential learning through engagement in the Pittsburgh Public Schools community will help CMU students make an impact on younger students, inspiring them to become familiar with and potentially pursue interdisciplinary technology careers.

67-220 Digital Accessibility - Ensuring Universal Access to the Information Society

Fall: 9 units
Digital accessibility addresses a user's ability to easily access an electronic document, a website, or a computer application unhindered by visual, auditory, motor or cognitive impairments or temporal disabilities arising from age, illness etc. Students who takes this course will gain a deep understanding of the diverse problems faced by people with disabilities in their interactions in a digital space and how the use of assistive technologies help them surmount the related accessibility barriers (CT1 and CT3). They will learn about inclusive design principles and how to author content with consideration of design decisions that impact digital accessibility. Besides gaining an understanding of user-centered design principles, the students will learn how to apply Web Content Accessibility Guidelines (WCAG) to design and develop a website (CT2). To cap it, students will learn how to test, evaluate and report conformance of a website with usability principles and accessibility standards. (CT3)

67-223 Digital Trace and Identity

All Semesters: 9 units
This course introduces students to the principles and applications of digital forensics. Students become aware of the digital traces they leave behind and how these traces can be used in forensics. Students are introduced to the typical life-cycle of a digital trace. They develop their practical digital investigation skills in computer laboratory classes by studying this life-cycle with the help of computer tools.

67-235 Puzzles, Games, and Problem Solving

Intermittent: 3 units
Puzzle-based learning (PBL) is a relatively new and model of teaching critical thinking and problem solving. Todays market place needs skilled graduates capable of solving real problems of innovation in a changing environment. A learning goal of PBL is to distill domain independent transferable heuristics for tackling problems. While solving puzzles is innately fun, companies such as Google and Yahoo also use puzzles to assess the creative problem solving skills of potential employees. In this micro-course we will examine a range of puzzles and games. What general problem solving strategies can we learn from the way we solve these examples? Students will emerge from this course with enhanced critial and creative thinking skills

67-240 Mobile Web Design & Development

Fall and Spring: 9 units
The Mobile Web Design and Development course provides a solid web design and development foundation focusing on responsive, user-centered design, and client-side components. Throughout the course, students work with HTML5, CSS3, Twitter Bootstrap, and JavaScript, and learn how the various web components function together. The course utilizes a hands-on approach to guide students through learning and understanding the design and development process. In this course, students work on in-class activities, individual assignments and a group project with a client using the current standards and best practices of web design and development. This course is primarily designed for students with minimal technical experience. By the end of the course, students will be able to plan, design, and implement a basic functioning mobile website/ app.
Prerequisites: 15-112 Min. grade C or 15-110 Min. grade C or 15-104 Min. grade C

67-250 The Information Systems Milieux

Spring: 9 units
Information systems (IS) are changing work practices, reshaping organizations, transforming cultures, and giving new meaning to the ways we see the world. This course is designed to help students understand the role of IS in the enterprise and the means by which these systems are created, utilized and maintained. The course will focus on enterprise information architecture including the components of enterprise strategy, business, application, information, and infrastructure layers. This course provides not only a framework for understanding information systems, but also a language to identify their dynamic complexities and interdependencies.

67-262 Database Design and Development

Fall: 9 units
Data driven decision making is a core process of organizations. In this class students will study the principles of database management systems, their design, and development. Recent alternatives to the classical relational model will also be examined.
Prerequisites: 15-121 or 15-112 or 15-122

67-265 Design Fundamentals: Shaping Interactions and Experiences

Fall: 9 units
This course offers hands-on experience based on theoretical grounding linked to fundamental design practices. The first fundamental idea is stakeholders need an interesting and organized pre-task environment as a precursor to engaging with a task. A pre-task environment is one that invites stakeholders to engage with and stay in a designed space because they can see that they will enjoy performing tasks that meet their goals. This useful, usable, and desirable task environment is developed by exploring compositional guidelines, color theory, and basic typography. With pre-task knowledge in hand, students explore meaning-making that emerges through the synthesis of image, word, and typeface as they design and prototype interactive solutions to problems that real users face, employing user studies and usability evaluations to create effective solutions.

67-272 Application Design and Development

Spring: 12 units
This course provides students with the concepts and techniques to design and develop software applications, and to understand the design process. Students will learn the importance of user-centered design and will develop a prototype of a web application as a course project. In the process of developing the application, students will learn how to design and create relational databases, how to acquire competency in new programming languages quickly, how to use the Model-View-Controller pattern to develop software applications, how to ensure technical quality in software development, and how to apply principles of user-centered design. This course is a required professional core course and is open only to sophomores and juniors in the IS major.
Prerequisites: (15-121 or 15-122) and 67-262

67-279 Introduction to Geographical Information Systems

Intermittent: 6 units
Geographical Information Systems (GIS) allow us to visualize information that uses location. Through displaying layers of information in computer generated maps, we can see, analyze, understand and explore spatial patterns and relationships in new and novel ways. People in many different fields use Geographical Information Systems in their work: for visualizing the environment, human development, demographics, traffic and transportation, public health and many more. In this course, students will learn the basics of GIS through hands-on experience with popular mapping tools. Sources of data, principles of coordinate and projection systems and elementary geo-analysis techniques will be included. Upon completion of the course, students will have the background to begin using GIS techniques in their own areas of interest and will be prepared for further study in advanced GIs courses.

67-285 Across the Universe from Intelligent Agents to Users

Spring: 9 units
The goal of this course is to introduce students to how intelligent agents and similar systems impact and are perceived by users. In this course, we explore different dimensions relating to intelligent agents' design, usability, and user perceptions such as humanness, trust, privacy, bias, human values, emotions, and so on. To do so, we review research articles at the intersection of Information Systems, Psychology and Artificial Intelligence. The course aims to introduce students to the research process and equip them with the necessary tools to design and explore research questions that address pressing issues in the realm of user-agent interaction.

67-306 Management of Computer and Information Systems

Spring: 6 units
The course provides the overall knowledge of how Information Technology departments are managed in organizations of all sizes. It is about the technology people, the necessary best practice processes, and how innovation occurs transforming organizations in the way they operate and compete.

67-309 Special Topics: Information Assurance and Security

Fall: 6 units
Special Topics: Information Assurance is an introduction course for Information Systems students that focuses on information security concepts. This course will be a broad introduction to many aspects of information security that affect computer systems, your everyday life on the internet, your activities - and those of others, and the practices of all organizations using and building information systems. You will learn an introduction to the practice of securing information systems, how organizations manage risk to their information assets, what threats there are to the security of an information systems, strategies for organizational resilience, applicable US cyber laws, and how organizations respond to real incidents. You will hear about some of the major cyber incidents that have shaped the way security is performed by organizations on the internet today, and you will participate through class discussions and homework analyzing important recent cyber issues, real incidents, and internet-scale events. By the end of the class you will be able to analyze systems for security using the language of security professionals and analyze the implications of real world attacks on security systems by applying core information security concepts.
Prerequisites: 15-110 or 15-112

67-319 Global Technology Consulting Groundwork

Spring: 3 units
This course is by invitation only for participants in the Technology Consulting in the Global Community program. For information on the program and how to apply, see URL below.

Course Website: http://cmu.edu/tcingc. (http://cmu.edu/tcingc.html)

67-331 Technology Consulting in the Global Community

Fall
This course is only for participants in the Technology Consulting in the Global Community program. Admitted ONLY BY Permission of Instructor

67-336 Building Data Visualizations in to Information Systems

Fall: 9 units
In an increasingly data-driven world, the ability to effectively understand complex information is crucial for problem-solving and decision-making. This course explores the art and science of designing interactive visualizations within information systems to allow data to be effectively communicated and understood. In other words, to allow the user to more easily and fully grasp the underlying story. Students in this course will gain a comprehensive understanding of the principles and theories underlying information design and visualization, including topics related to information architecture, human computer interaction, user-centered design, human perceptual and cognitive factors and how to leverage them to effectively communicate information. Students will also learn how these visualizations can be integrated into the software design process and how visualizations improve the value of information systems. Through a well-balanced breadth and depth of lectures, exercises and projects, students will learn to use popular design tools and technologies to design information systems and create visualizations that facilitate understanding, analysis, assessment and evaluation of various data sets and selected information systems. One of the important aspects of this course is to foster students' cultural and socioeconomic awareness, promote responsible technology use, and empower them to apply technical skills to address social inequalities for positive societal impact.

67-338 Information & Grid Design

Fall: 9 units
Whether you create, oversee, or want practice solving problems through grid systems for websites, responsive applications, slide presentations, or data visualizations, this course provides the skills and perspective needed to communicate in grid environments: a synthesis of content, structure, and interaction. Grids emerged to address content/structure needs linked to print production, leaving opportunities to fully explore how they can better help stakeholders in interactive environments. As we explore this space, specific skillsets will include: developing a better understanding of visual composition through the grid, using the vocabulary of communication and information design in critique, manipulating typographic variables to create readable documents, learning approaches to invention using image, text, and amp; typography, creating simple to complex grid structures, developing skills in Illustrator, Photoshop, and Adobe XD, adapting simple prototypes to HTML/CSS through basic Bootstrap.

67-346 Blockchain Fundamentals

Intermittent: 6 units
In this course, we will dig into the blockchain technology. We will learn from the basic, single-purpose blockchain (such as for Bitcoin) to general purpose blockchain (which includes a range of use-cases). The course will cover a broad spectrum of blockchain technology, different consensus algorithms, its various real-world use-cases with an eye on developing our own blockchain. We will also understand various challenges with this technology, and a case-study that covers implementation in Python. This would be an interactive course and the students are expected to share ideas and their thoughts.

67-348 Black Mirror - Cultural Representations of Technology

Fall: 9 units
Advances in technology raise a variety of fascinating ethical, cultural, and societal questions often resulting in uncertainties and unanticipated dilemmas. This course provides an opportunity to explore how cultural representations of technology are reflected in society and inform continued technical advancements. Using episodes from Black Mirror - a British anthology television series created by Charlie Brooker - we will explore the depictions of technology and society and its representation. This course will challenge you to think critically about technological change and controversial topics surrounding digital culture and social impact. You will also develop a more sophisticated understanding of the political, economic, and cultural considerations that underlie technological development. Discussions of episodes will be supplemented by popular, critical texts and academic articles. This class is more seminar-based, rather than lecture-based. We will engage critically and constructively in key debates that shape the future of the technology, through in-class discussions, activities, and presentations.

67-364 Practical Data Science

Spring: 9 units
From empirical, to theoretical, to computational science, we are at the dawn of a new revolution and #8212;-a fourth paradigm of science driven by data. Like archaeological remnants, data, by its very nature, is a marker of what happened in the past. How can data be used to better understand this past and what is happening in the present? How can data be leveraged to forecast what will happen in the future? Better still, how can data be used to mold what should happen in the future? In this course we will study descriptive, predictive, and prescriptive methods by which data can be used to gain insight and inform actions of people and organizations. The real excitement of data science is in the doing. This is an application oriented course requiring skill in algorithmic problem solving. We will use Python based data science tools. While prior programming experience with Python will be helpful the course will strive to be self-contained. If you have not programmed in Python before, you need to be comfortable programming in some language (e.g., Ruby, R, Java, C++) and will need to come up to speed with the Pythonic way of problem solving.
Prerequisites: (36-200 Min. grade C or 36-201 Min. grade C) and 15-112 Min. grade C

67-367 Information Warfare

Intermittent: 9 units
In this course, we will examine information warfare through technical as well as strategic, operational, and tactical employment perspectives. This course will address historical aspects of military deception, electronic warfare, computer network operations, operational security, and psychological operations

67-368 User Experience (UX) Research for Product Managers

Fall: 9 units
User Experience (UX) saturates the digital landscape, often acting as the pivotal determinant of user engagement with a product or service. Mastery of UX research is crucial for product managers, serving as the cornerstone for steering development efforts towards the attainment of cutting-edge user experiences. This course is geared towards providing understanding of the pivotal role of UX within the realm of product management, equipping students with the requisite arsenal of tools to research, obtain, and leverage UX insights for the development of products. The curriculum introduces UX principles, and delves in UX research methodologies, and their practical application through advanced digital experimentation. Through participation in hands-on exercises within a state-of-the-art digital laboratory environment, participants will go on the iterative journey from problem identification to the delivery of definitive solutions, thereby fine-tuning their acumen in elevating UX across the product lifecycle. By integrating theoretical paradigms with experiential learning, this course empowers participants to deftly navigate the intricacies of UX research, catalyzing the creation of next-generation, user-centric digital innovations.
Prerequisites: 36-200 or 70-207 or 36-220

67-373 Information Systems Consulting Project

Spring: 12 units
In this course, students design and implement a usable information system for a client. The client may be affiliated with the university, government, business, or non-profit agency. Students will be assigned to teams to work on these projects, and will produce operational, fully documented and tested, computer-based information systems. The projects will be supervised by CMU faculty and, when possible, by project clients.
Prerequisite: 67-272

67-380 Information Systems Security

Intermittent: 9 units
This course is an introduction to information systems security for the IS student. The course will introduce the student to fundamental concepts in information system security, including operational issues, planning, and design. Topics will include confidentiality, integrity, and availability; risk; access controls and access control frameworks; security policies; authentication strategies and issues; auditing; using cryptography; security design issues; controlling information flows; malicious logic; and applying security principles

67-384 Digital and Cybercrime

Fall: 9 units
This course will discuss various types of cybercrime and ways to deal with them. Students will learn who are doing this cybercrime, and how the technology and people's psychology can be manipulated by them to do a cybercrime. Taking multimedia-based cybercrime as an example, the course, will then discuss how to deal with such cybercrime. To that end, students will be introduced various multimedia-based cybercrime tools, and they will develop their practical digital investigation skills through the use of computer laboratory classes. Cybercrime involving the advanced technologies, such as deepfake, LLM, etc. will also be introduced.
Prerequisite: 15-112

67-390 Independent Study in Information Systems

Fall and Spring
Independent studies are opportunities to engage in research with an IS faculty member to advance your learning in certain areas of interest. Information Systems students may enroll in independent study for 3, 6, 9, or 12 units of academic credit by obtaining an IS faculty sponsor who will oversee the academic component of the coursework, monitor progress, and assign a final grade. This is available by Special Permission.

67-391 Independent Study in Information Systems

Fall and Spring
Independent studies are opportunities to engage in research with an IS faculty member to advance your learning in certain areas of interest. Information Systems students may enroll in independent study for 3, 6, 9, 12 units of academic credit by obtaining an IS faculty sponsor who will oversee the academic component of the coursework, monitor progress, and assign a final grade.

67-393 Guided Research in Information Systems

All Semesters
This course is for team-based research with an IS faculty member. Upon prior approval by the faculty member, students may enroll for 3, 6, 9, or 12 units.

67-404 Blockchain Applications

Intermittent: 9 units
In this course, we will dig into the blockchain technology. We will learn from the basic, single-purpose blockchain (such as for Bitcoin) to general purpose blockchain (which includes a range of use-cases). The course will cover a broad spectrum of blockchain technology, different consensus algorithms, its various real-world use-cases - with an eye on developing our own blockchain. We will also understand various challenges with this technology, and a case-study that covers implementation in Python. This would be an interactive course and the students are expected to share ideas and their thoughts.

67-410 Clinical Data Science

Intermittent: 9 units
This course is designed as an introductory course in Critical Care Data Science, providing an introduction to the tools and techniques of data science, specifically focused on clinically relevant critical care. Electronic Medical Records; Common Data Models for Clinical Data; SQL Querying; Computational Phenotyping; Common Machine Learning Techniques (Supervised; Unsupervised; Reinforcement Learning); and Reporting Clinical Data Science Research.

67-415 Cyber Ethics and Regulation

Intermittent: 9 units
This course investigates the ethical and regulatory implications of technology by adopting a four-dimensional framework focused on Privacy, Accuracy, Property, and Accessibility (PAPA Framework. It examines legal rights and corresponding duties and responsibilities of stakeholders. The course delves into established and emergent themes including cyber law, surveillance, dis/misinformation, artificial intelligence, intellectual property, cybersecurity, and organizational policy. Its primary focus is on social, behavioral, and legal implications of technology, assessed from multiple perspectives pertaining to individuals, organisations and societies.

67-417 Web Investigation and Surveillance

Spring: 9 units
In this course, students will learn about web investigation and surveillance which are required to deal with network-based attacks and crime. On completion, students will have an understanding of how network-based attacks and crime happens and how to deal with them. To that end, students will be introduced to topics such as intrusion detection, incidence response, internet investigation, etc. Students will also be introduced to new types of network attacks and crime arisen due to the advancement of technology. Students will develop their practical skills to mitigate network attacks and crime through the use of computer laboratory classes.
Prerequisites: 67-380 and 67-301

67-421 Advanced Topics in Information Systems: Visualizations

Fall: 9 units
Advanced topics in IS visualizations

67-425 Special Topics - Capstone course in Digitalization

Intermittent: 9 units
Most organizations including your future employers use enterprise systems to run their business processes such as sales, procurement, and production. This course discusses key business processes in organizations and the role, functions and technical foundations of enterprise systems such as Enterprise Resource Planning (ERP) systems and Customer Relationship Management (CRM) systems. Through hands-on use of enterprise systems in multiple case studies, the students will become familiar with the key concepts in such systems and demonstrate practical knowledge on how such systems allow organizations to run end-to-end business processes such as order-to-cash or make-to-order. The course also addresses the lifecycle of enterprise systems' projects and their various phases such as selection, implementation, operation and maintenance.

67-426 Special Topics - Capstone course in Data Science

Intermittent: 9 units
TBA

67-427 Privacy and Security Capstone

Fall and Spring: 9 units
This course is the capstone course for the Privacy and Security concentration in Information Systems. It requires students to engage in a substantive project related to Privacy and/or Security that will be primarily independent but guided by faculty.

67-430 AI and Emerging Economies

Intermittent: 9 units
In this course, we will explore the intersection of artificial intelligence (AI) with emerging economies. Our focus will extend beyond traditional AI research and development to address the unique challenges and opportunities faced by countries experiencing rapid economic growth. Through a combination of theoretical discussions, case studies, and practical projects, students will gain insights into how AI can drive positive change in diverse socio-economic contexts.

67-435 Advanced Topic in Information Systems:

Fall: 9 units
Advanced topic in IS

67-443 Mobile Application Design and Development

Fall: 12 units
This course provides students with the concepts and techniques to design and develop innovative mobile applications. Students will develop a series of smaller mobile applications in weekly lab sessions (using either iOS or Android frameworks). In addition, student teams will build a larger mobile application, as part of a semester-long project, that fills a demand not effectively met in the current market. In the process of developing these applications, students will gain a strong understanding of mobile application development, mobile-centered design, the process of creating and testing innovative application design, and larger principles of software engineering. In weekly labs, students can choose either the Swift/iOS or Kotlin/Android track to complete course work, but lectures will primarily use Swift to illustrate larger points of software architecture and engineering. This course is open only to seniors in the IS major.
Prerequisite: 67-272 Min. grade C

67-490 Practicum in Information Systems

Intermittent
This course is offered only at Carnegie Mellon's campus in Qatar. The practicum in information systems allows students interested in applying skills acquired in the field of information systems in the context of a working environment. Students will complete a project and be accountable to a stakeholder that is external to their program of study. They may shadow and observe practices in the field of information systems, and also perform tasks as assigned. A hands-on experience is expected. By completing this course, students practice desirable skills for employability, such as time management, project management, team work, and professional development.

67-505 Information Systems Internship

Fall and Spring
Practical experience in Information Systems.

67-738 Information & Grid Design

Fall: 9 units
Whether you create, oversee, or want practice in solving problems through grid systems for websites, responsive applications, slide presentations, or data visualizations, this course provides the skills needed to communicate using the interplay of image, text, and typography in grid environments.

Department of Philosophy

Peter Sprites, Department Head

Location: Baker Hall
www.cmu.edu/dietrich/philosophy (http://www.cmu.edu/dietrich/philosophy/)

The Department of Philosophy was founded in 1985 and reflects the tradition of philosophy as a central discipline in the humanities. The department has achieved an international reputation through the acclaimed research of its members and its innovative educational programs, not only in traditional topics such as ethics, philosophy of mind, logic, and theory of knowledge, but in such contemporary and applied areas as automated theorem proving, machine learning, the foundations of statistics, causal discovery, forward learning theory, game and decision theory, conflict resolution, and business ethics.

Philosophy thrives through contact with other disciplines. Interdisciplinary work, a traditional strength of the Carnegie Mellon community, is vital to the department and is reflected in the courses we offer, many of which incorporate substantive material from a range of other disciplines. Some courses are actually team-taught with professors from other departments and schools around the university.

Our programs are designed to develop our students' analytical sophistication and their practical and theoretical skills in specializations outside the department (see the sample curricula below). The department welcomes and, indeed, encourages minors and additional majors from other disciplines who are interested in reflecting on the foundation of their own subjects. The department offers three different undergraduate major programs, and jointly sponsors an interdepartmental major: Ethics, History, and Public Policy (with the Department of History):

- the B.A. or B.S. in Ethics, History, and Public Policy (interdisciplinary major with Department of History)
- the B.S. in Logic and Computation
- the B.A. in Philosophy
- the B.A. in Linguistics

The major in Logic and Computation is perhaps the most non-traditional of the department's majors. It offers students a firm background in computer science, together with a solid grounding in logic, philosophy, and mathematics. This reflects the department's commitment to the use of formal, analytic methods in addressing philosophical issues. A flexible system of electives allows students to focus their efforts in any of a wide range of disciplines, from engineering to the fine arts. As a capstone to the program, students engage in original research in their senior year, and write a thesis under the direction of an advisor.

The department also sponsors six minor programs:

- the minor in Ethics
- the minor in Linguistics
- the minor in Logic and Computation
- the minor in Philosophy
- the minor in Rationality, Uncertainty, and Choice: Formal Methods (RUC)
- the minor in Societal & Human Impacts of Future Technologies (SHIFT)

Finally, the department offers two master's programs directly extending the departmental majors. Both programs are coordinated with and build on the undergraduate programs, so that majors can complete the requirements for the master's degree in one additional year:

- the M.S. in Logic, Computation and Methodology
- the M.A. in Philosophy

The Major in Ethics, History, and Public Policy

Professor Steven Schlossman, Director of Ethics, History, and Public Policy, History Department
Location: Baker Hall 236A, 412-268-2880
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The B.A./B.S. in Ethics, History, and Public Policy (EHPP) is an interdepartmental major offered jointly by the Departments of History and Philosophy.

Preparing students to be leaders is a vital goal of colleges and universities in every democratic society. The intellectual challenges facing public and private sector leaders have expanded dramatically since the pioneering EHPP program began in 1996, but the need remains as great as ever for broadly educated, ethically sensitive, and technically skilled leaders.

EHPP prepares students to demonstrate sophistication and flexibility in their command of interdisciplinary knowledge; deep historical understanding of how modern-day policy problems have emerged and evolved; and clear, rational criteria for ethical and socially just decision making. The curriculum provides students with a strong humanistic foundation for developing such high-level, historically grounded, and ethically attuned leadership capacities. It also offers ample room for specialization in a wide range of policy areas in which the History and Philosophy departments have special expertise, e.g., medicine and public health, criminal justice, environment, technology, artificial intelligence (AI), gender, civil rights, immigration, and education.

Curriculum

Students seeking a primary major in Ethics, History, and Public Policy may elect to receive either a Bachelor of Arts or a Bachelor of Science degree (additional requirements apply; see below). Basic requirements include 120 units encompassing 45 units in History, 45 units in Philosophy, 18 units in Law and Social Science, and a 12-unit EHPP Capstone Course. This program may also be taken as an additional (i.e., second) major. All courses toward the major must be taken for a letter grade and must be passed with a grade of "C" or better. Students can double count any course for the major with another major or minor, with the exception of Social and Political History, for which a student can double count a maximum of two courses.

I. Foundation Courses in History and Philosophy **18 units**

Choose one of the following two courses:

79-189	Democracy and History: Thinking Beyond the Self	9
79-248	U.S. Constitution & the Presidency	9

Choose one of the following two courses:

80-130	Introduction to Ethics	9
80-330	Ethical Theory	9

II. Ethics and Policy Core 36 units

Choose four of the courses below:

No more than one course may be taken at the 100 level and at least one course must be taken at the 300 level or above.

80-135	Introduction to Political Philosophy	9
80-136	Social Structure, Public Policy & Ethics	9

80-208	Critical Thinking	9
80-221	Philosophy of Social Science	9
80-234	Race, Gender, and Justice	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-249	AI, Society, and Humanity	9
80-305	Game Theory	9
80-306	Decision Theory	9
80-324	Philosophy of Economics	9
80-330	Ethical Theory	9
80-335	Social and Political Philosophy	9
80-336	Philosophy of Law	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9

III. History and Policy Core 36 units

Choose four of the courses below:

79-175	Moneyball Nation: Data in American Life	9
79-204	American Environmental History	9
79-212	Jim Crow America	9
79-215	Environmental Justice from Conservation to Climate Change	9
79-234	Technology and Society	9
79-242	African American History: Reconstruction to the Present	9
79-248	U.S. Constitution & the Presidency	9
79-250	Voting Rights: An Introduction	9
79-278	How (Not) to Change the World	9
79-300	Controversial Topics in the History of American Public Policy	9
79-320	Women, Politics, and Protest	9
79-321	Documenting Human Rights	9
79-330	Medicine and Society: Health, Healers, and Hospitals	9
79-343	Education, Democracy, and Civil Rights	9
79-360	Crime, Policing, and the Law: Historical and Contemporary Perspectives	9
79-370	Technology in the United States	9
79-380	Hostile Environments: The Politics of Pollution in Global Perspective	9

IV. Foundation Courses in Law and Social Science 18 units

Choose two of the courses below:

17-200	Ethics and Policy Issues in Computing	9
19-101	Introduction to Engineering and Public Policy	12
70-332	Business, Society and Ethics	9
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
84-104	Decision Processes in American Political Institutions	9
84-110	The Economics of Politics, Policy, and Technology	9
84-352	Representation and Voting Rights	9
84-393	Legislative Decision Making: US Congress	9
84-402	Judicial Politics and Behavior	9
88-281	Topics in Law: 1st Amendment	9
88-284	Topics of Law: The Bill of Rights	9

EHPP students will also be able to complete the Foundations of Law and Social Science category by participating in the Washington Semester Program. Students are encouraged to pursue additional policy-relevant courses in law and social science, along lines consistent with their career ambitions.

V. EHPP Capstone Course 12 units

In Fall semester of senior year, EHPP students will participate in an interdisciplinary capstone course that asks students to integrate their studies in Ethics and History by addressing a policy topic of contemporary national urgency (e.g., climate change, immigration, infrastructure, abortion, hate speech, reparations, law enforcement and policing, charter schools, affirmative action, vaccination, taxation, voting rights, global justice). The Departments of History and Philosophy will alternate teaching the EHPP Capstone Course.

79-449	EHPP Capstone Course [cross-listed]	12
80-449	EHPP Capstone Course [cross-listed]	12

VI. Bachelor of Science Option

Students may elect to earn a Bachelor of Science rather than a Bachelor of Arts degree by completing two courses from the list below, or by petitioning the Director of EHPP to accept equivalent courses as substitutions.

21-257	Models and Methods for Optimization	9
36-202	Methods for Statistics & Data Science	9
or 70-208	Regression Analysis	
36-303	Sampling, Survey and Society	9
36-309	Experimental Design for Behavioral & Social Sciences	9
70-257	Optimization for Business	9
80-305	Game Theory	9
80-306	Decision Theory	9
88-221	Markets, Democracy, and Public Policy	9
88-223	Decision Analysis	12
88-251	Empirical Research Methods	9
88-300	Programming and Data Analysis for Social Scientists	9

Additional Major

The B.A./B.S. in Ethics, History, and Public Policy may be scheduled as an additional major in consultation with the Director of Ethics, History, and Public Policy.

Ethics, History, and Public Policy Sample Curriculum

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
Foundations Course in History	Foundations Course in Law and Social Sciences	EHPP Capstone Course	Ethics and Policy Core Course
Foundations Course in Philosophy	Foundations Course in Law and Social Sciences	Ethics and Policy Core Course	History and Policy Core Course
Ethics and Policy Core Course	Ethics and Policy Core Course	History and Policy Core Course	Third Course (open)
History and Policy Core Course	History and Policy Core Course	Fourth Course (open)	Fourth Course (open)
Fifth Course Open	Fifth Course (open)	Fifth Course (open)	Fifth Course (open)

The above sample program is presented as a two-year (junior-senior year) plan for completing EHPP major requirements. Its purpose is to show that this program can be completed in as few as two years; not that it must be.

Students may enter the EHPP major, and begin major course requirements, as early as they wish. Students should consult their advisor when planning their program.

The Major in Linguistics

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Linguistics is the scientific study of human language. The central goal of the Linguistics Major is to provide students with the analytical skills and linguistic concepts needed to understand language scientifically, whether formally, as researchers, or informally, as participants in daily linguistic interactions. The foundation of the Linguistics Major is a set of rigorous core courses, informed by contemporary approaches to the study of linguistic form and meaning.

The **Core courses** cover the principal domains of linguistic analysis: phonetics and phonology, syntax and meaning.

Students then move on to the **Extended Core**, which includes more advanced courses as well as courses on a wider range of topics, such as intonation and language variation. These courses are supplemented by a wide-ranging set of electives including linguistically relevant courses taught in other departments.

Primary majors complete their course of study with a Senior Thesis, a semester-long research project carried out independently with one-on-one guidance from a member of the linguistics faculty.

Curriculum

The Linguistics **primary major** requires a total of 12 courses plus a senior thesis. The Linguistics **additional major** requires a total of 13 courses (senior thesis not required). This includes 2 semesters of sequential language study for all majors. At least three courses (not including specific language courses) must be at the 300-level or higher. All courses counted towards the major must be taken for a letter grade and passed with a grade of "C" or above. Students may double count any course for the major simultaneously with another major or minor.

Linguistics Core (36 units)

Complete the following requirements.

80-180	Nature of Language: An Introduction to Linguistics	9
80-282	Phonetics and Phonology I	9
80-280	Linguistic Analysis	9
or 80-285	Natural Language Syntax	
80-381	Meaning in Language	9
or 80-383	Language in Use	

Extended Core (27 units)

Choose three courses (27 units) from Extended Core and/or additional courses from Linguistics Core.

80-283	It Matters How You Say It	9
80-286	Words and Word Formation: Introduction to Morphology	9
80-287	Language Variation and Change	9
80-288	Intonation: The Meaning of Linguistic Tunes	9
80-382	Phonetics and Phonology II	9
80-384	Linguistics of Turkic Languages	9
80-385	Linguistics of Germanic Languages	9
80-388	Linguistic Typology: Diversity and Universals	9
80-488	Acoustics of Human Speech: Theory, Data, and Analysis	9

LANGUAGE REQUIREMENT

Students must successfully complete 2 semesters of foreign language study in a single language (e.g. 100 & 200 level).

Electives

Primary majors choose **three** additional electives (27 or more units). Additional majors choose **four** additional electives (36 or more units). *Primary majors: see thesis requirement below.*

These Electives can be additional courses from the Core or Extended Core courses listed above, the electives list below, or any other course which is approved by the Academic Program Manager as a linguistics elective. Listed below are the additional electives taught on a regular basis. Additional appropriate courses are offered irregularly or on a one-off basis. The Academic Program Manager will provide students with a list of possible electives each semester, and will assist students in selecting electives which are consistent with their goals and interests.

Philosophy		
80-484	Language and Thought	9
English		
76-318	Communicating in the Global Marketplace	9
76-325	Intertextuality	9
76-385	Introduction to Discourse Analysis	9
76-386	Language & Culture	9
76-388	Coding for Humanists	9
76-389	Rhetorical Grammar	9
Modern Languages		
82-239	Crazy Linguistically Rich Asian Languages	9
82-304	French & Francophone Sociolinguistics	9
82-305	French in its Social Contexts	9
82-334	Structure of Chinese	9
82-585	Topics in Second Language Acquisition	9
82-373	Structure of the Japanese Language	9
82-383	Second Language Acquisition: Theories and Research	9
82-388	Topics in Second Language Acquisition	9
Psychology		
85-354	Infant Language Development	9
85-421	Language and Thought	9
Language Technologies Institute		
11-411	Natural Language Processing	12
11-423	ConLanging: Lrng. Ling. & Lang Tech via Constru Artif. Lang.	12
11-492	Speech Technology for Conversational AI	12
11-422	Grammar Formalisims	12

Note: all 11-xxx courses have significant Computer Science prerequisites. Interested students should check with the course instructor and with the Linguistics Academic Program Manager before registering.

Statistics and Data Science		
36-468	Special Topics: Text Analysis	9

SENIOR THESIS [PRIMARY MAJORS ONLY]

Primary majors must complete a senior thesis (a workload equivalent to a 12-unit course) 80-595 Senior Thesis. Topics must be approved by an advisor, who will work with the student and guide the thesis project. Students are responsible for identifying their topic and securing their thesis advisor. Students should work with the Academic Program Manager of the major to begin the process of identifying their thesis topic and advisor during the fall of their senior year at the latest. Students will be required to submit a written proposal of their thesis project, signed by their thesis faculty advisor, before the end of the semester preceding that in which the thesis research will be conducted..

Additional Major in Linguistics

The Linguistics additional major requires a total of 13 courses. This includes 2 semesters of language study for all majors. At least three courses (not including specific language courses) must be at the 300-level or higher. Additional majors are not required to write a thesis but must take four electives (36 or more units). All courses counted towards the major must be taken for a letter grade and passed with a grade of "C" or above. Students may double count any course for the major simultaneously with another major or minor. If you are interested in obtaining an additional major in Linguistics, please reach out to the Academic Program Manager, Philosophy Department.

The Major in Logic and Computation

Patrick Doyle, *Academic Program Manager*
Location: Baker Hall 161G
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The Bachelor of Science in Logic and Computation curriculum takes advantage of the preparation provided by the Dietrich College General Education Program in mathematics, philosophy, psychology, and statistics. It is flexible in that it permits students to focus on any of a number of areas including (but not limited to):

- computer science,
- artificial intelligence and cognitive science,
- logic and the foundations of mathematics,
- methodology and philosophy of science.

Curriculum

The course requirements for the major consist of seven core courses (including the Senior Thesis) and four electives. The core courses provide comprehensive background in logic, computability, and analytic philosophy.

Students in their first year and sophomore year, are expected to take three courses that provide preparation in computer science, mathematics, and statistics. Four advanced electives are chosen in the area of focus, as described below in the sample curricula, and should support independent research towards fulfilling the senior thesis requirement. In their senior year, **Primary and Additional Majors** in Logic and Computation will engage in original research under the supervision of a faculty advisor in 80-595 Senior Thesis (a workload equivalent of 12 units). Students are responsible for identifying a thesis topic and securing a faculty advisor prior to the start of the semester in which they plan to complete the thesis. Note: Students should work with the Academic Program Manager during their junior year to begin the process of identifying their topic and potential advisors. However, with suitable planning and advice from the Academic Program Manager, it is possible to complete the program in two years, beginning in the junior year.

All courses, if taken at Carnegie Mellon University, must be taken for a letter grade and passed with a grade of "C" or above. Students may double count any course for the major with another major or minor.

Prerequisites — 42 units

80-211	Logic and Mathematical Inquiry	9
36-200	Reasoning with Data	9
15-112	Fundamentals of Programming and Computer Science	12
21-127	Concepts of Mathematics	12

Logic and Computation Core — 63 units

80-150	Nature of Reason *Students should complete before their junior year.	9
80-310	Formal Logic *Students should complete before their junior year.	9
80-311	Undecidability and Incompleteness	9
15-122	Principles of Imperative Computation *Students should complete this prerequisite before their junior year.	12
15-150	Principles of Functional Programming *Students should complete this prerequisite before their junior year.	12
80-595	Senior Thesis	12

Logic and Computation Electives — 36 units

Bearing in mind prerequisites, Logic and Computation majors must complete four advanced courses in areas that use logical and computational tools, such as philosophy, computer science, linguistics, mathematical logic, psychology, or statistics. The sequence of courses, mostly at the *300-level and above, must be selected in consultation with the Academic Program Manager.

Sample Curricula

Below are four samples of Logic and Computation curricula (beyond the core courses), each reflecting a different emphasis: Computer Science, Language and Information Technology, Artificial Intelligence and Cognitive Science, Logic and the Foundations of Mathematics, and Methodology.

Sample 1.
A student interested in **Computer Science** might take the following courses:

80-315	Logics for Knowledge and Belief	9
80-413	Category Theory	9
15-312	Foundations of Programming Languages	12
15-317	Constructive Logic	9

Sample 2.
A student interested in **Artificial Intelligence and Cognitive Science** might take the following courses:

80-249	AI, Society, and Humanity	9
80-315	Logics for Knowledge and Belief	9
80-325	Foundations of Causation and Machine Learning	9
80-411	Proof Theory	9
85-412	Cognitive Modeling	9

Note: If you are a Cognitive Science (https://www.cmu.edu/dietrich/psychology/undergraduate/prospective-students/academics/cognitive-science/) major (Department of Psychology) this additional major would complement your coursework.

Sample 3.
A student interested in **Logic and the Foundations of Mathematics** might consider the following courses:

80-254	Analytic Philosophy	9
80-312	Mathematical Revolutions	9
80-411	Proof Theory	9
80-413	Category Theory	9

Sample 4.
A student interested in **Methodology** might consider the following courses:

80-220	Philosophy of Science	9
80-221	Philosophy of Social Science	9
36-309	Experimental Design for Behavioral & Social Sciences	9
80-305	Game Theory	9

Additional major in Logic and Computation

The Logic and Computation major is also suitable as an additional major for students in Dietrich College or for students in other colleges within the University. Non-Dietrich students interested in an additional major in Logic and Computation need to take only those courses in the Dietrich College General Education Program that are prerequisites to courses required in the major; all other Dietrich College General Education requirements are waived for these students. Depending on the student's background, the requirements of the additional major in Logic and Computation can be fulfilled with as few as five additional courses. The Philosophy Department does not limit the number of courses that can be counted for other majors and minors around the university. In their senior year, the additional major in Logic and Computation will write a thesis under the supervision of a faculty advisor.

The M.S. Program in Logic, Computation and methodology

The Department of Philosophy also offers a graduate M.S. degree in Logic and Computation and Methodology, which culminates with the writing of a master's thesis. It is ordinarily a two-year program, but students in the Logic and Computation major are able to complete the additional requirements in one year. Interested students in the 5th-year Master's program (https://www.cmu.edu/dietrich/philosophy/graduate/5th-year-masters.html)Master of Science in Logic, Computation & Methodology, should contact the Academic Program Manager for more information on how to apply.

The Major in Philosophy

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The Major in Philosophy is intended to be flexible and to facilitate additional majors in other fields (including majors with a strong professional focus). It provides students with a broad humanities education and sharpens their analytical skills. We encourage, but do not require, students to choose a thematic concentration through their electives. Sample curricula emphasizing Law and Social Policy, Philosophy of Science, Ethics and Social Philosophy, and Philosophy of Mind are suggested below. However, alternative emphases can be proposed and approved by the Academic Program Manager. The Major in Philosophy is a B.A. degree.

Curriculum

In addition to the general education requirements for the student's college, Philosophy primary majors and additional majors must complete 80-100 Introduction to Philosophy and nine Philosophy courses in the Areas listed below. The 80-100 Introduction to Philosophy requirement must be fulfilled before the first semester of the junior year. Only two of the remaining nine courses may be at the 100-level, and two of the nine courses must be at the 300-level or higher. All ten courses, if taken at CMU, must be taken for a letter grade and passed with a grade of "C" or above. No more than two of the ten courses may be taken at another institution. Students are to choose one course out of each of the areas 1-4, two courses out of area 5, and may freely select three courses in area 6. Students may double count any course for the major with another major or minor. As per the requirement of Dietrich College, a student's Grand Challenge First-Year Seminar course may not count toward the fulfillment of the major requirements.

Introduction to Philosophy — 9 units

80-100	Introduction to Philosophy	9

Area 1: Values and Normative Theory — 9 units

One of the following:

80-130	Introduction to Ethics	9
80-135	Introduction to Political Philosophy	9
80-136	Social Structure, Public Policy & Ethics	9
80-234	Race, Gender, and Justice	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-246	Moral Psychology	9
80-249	AI, Society, and Humanity	9
80-330	Ethical Theory	9
80-335	Social and Political Philosophy	9
80-336	Philosophy of Law	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9

Area 2: Philosophy of Mind/Language/Metaphysics — 9 units

One of the following:

80-180	Nature of Language: An Introduction to Linguistics	9
80-270	Problems of Mind and Body: Meaning and Doing	9
80-271	Mind and Body: The Objective and the Subjective	9
80-276	Philosophy of Religion	9
80-280	Linguistic Analysis	9
80-282	Phonetics and Phonology I	9
80-283	It Matters How You Say It	9
80-285	Natural Language Syntax	9
80-286	Words and Word Formation: Introduction to Morphology	9
80-287	Language Variation and Change	9
80-288	Intonation: The Meaning of Linguistic Tunes	9
80-381	Meaning in Language	9
80-382	Phonetics and Phonology II	9
80-383	Language in Use	9
80-384	Linguistics of Turkic Languages	9
80-385	Linguistics of Germanic Languages	9
80-388	Linguistic Typology: Diversity and Universals	9
80-484	Language and Thought	9
80-488	Acoustics of Human Speech: Theory, Data, and Analysis	9

Area 3: Logic/Philosophy of Mathematics — 9 units

One of the following:

80-210	Logic and Proofs	9
80-211	Logic and Mathematical Inquiry	9
80-212	Arguments and Logical Analysis	9
80-310	Formal Logic	9
80-311	Undecidability and Incompleteness	9
80-312	Mathematical Revolutions	9
80-315	Logics for Knowledge and Belief	9
80-411	Proof Theory	9
80-413	Category Theory	9
80-419	Interactive Theorem Proving	9
80-514	Categorical Logic	9

Area 4: Epistemology/Methodology — 9 units

One of the following:

80-150	Nature of Reason	9
80-201	Knowledge and Justified Belief	9
80-208	Critical Thinking	9
80-220	Philosophy of Science	9
80-221	Philosophy of Social Science	9
80-226	The Nature of Scientific Revolutions	9
80-261	Experience, Reason, and Truth	9
80-305	Game Theory After Spring 2023	9
80-306	Decision Theory	9
80-324	Philosophy of Economics	9
80-325	Foundations of Causation and Machine Learning	9
80-405	Game Theory Prior to Fall 2023	9
80-516	Causality and Machine Learning	9
80-521	Seminar on Formal Epistemology: Belief and Evidence	9
80-524	Topics in Formal Epistemology: Topological Philosophy of Science	9

Area 5: History of Philosophy — 18 units

Two of the following:

80-150	Nature of Reason	9
80-226	The Nature of Scientific Revolutions	9
80-250	Ancient Philosophy	9
80-251	Modern Philosophy	9
80-252	Kant	9
80-253	Continental Philosophy	9
80-254	Analytic Philosophy	9
80-551	Seminar on History of Philosophy: Smith and Hume	9
80-261	Experience, Reason, and Truth	9
80-350	Adam Smith	9
80-358	Hume	9
80-365	Ramsey	9

Area 6: Elective — 27 units

Three other philosophy courses, or appropriate courses from other departments, with the permission of the Academic Program Manager.

Sample Curricula

Here are four sample curricula, reflecting different emphases.

1. For an emphasis on Law & Social Policy, a student might take:

Area 1		
80-335	Social and Political Philosophy	9
Area 2		
80-180	Nature of Language: An Introduction to Linguistics	9
Area 3		
80-211	Logic and Mathematical Inquiry	9
Area 4		
80-208	Critical Thinking	9
Area 5		
80-150	Nature of Reason	9
80-250	Ancient Philosophy	9
Area 6		
80-336	Philosophy of Law	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9

2. For an emphasis on Philosophy of Science, a student might take:

Area 1		
80-136	Social Structure, Public Policy & Ethics	9
Area 2		
80-270	Problems of Mind and Body: Meaning and Doing	9
Area 3		
80-211	Logic and Mathematical Inquiry	9
Area 4		
80-220	Philosophy of Science	9
or 80-221	Philosophy of Social Science	
Area 5		
80-250	Ancient Philosophy	9
80-226	The Nature of Scientific Revolutions	9
Area 6		
80-150	Nature of Reason	9
80-221	Philosophy of Social Science	9
80-524	Topics in Formal Epistemology: Topological Philosophy of Science	9

3. For an emphasis on Ethics and Social Philosophy, a student might take:

Area 1		
80-130	Introduction to Ethics	9
Area 2		
80-276	Philosophy of Religion	9
Area 3		
80-211	Logic and Mathematical Inquiry	9
Area 4		
80-221	Philosophy of Social Science	9
Area 5		
80-250	Ancient Philosophy	9
80-251	Modern Philosophy	9
Area 6		
80-330	Ethical Theory	9
80-335	Social and Political Philosophy	9
80-348	Health, Human Rights, and International Development	9

4. For an emphasis on Philosophy of Mind, a student might take:

Area 1		
80-130	Introduction to Ethics	9
Area 2		
80-270	Problems of Mind and Body: Meaning and Doing	9
Area 3		
80-211	Logic and Mathematical Inquiry	9
Area 4		
80-201	Knowledge and Justified Belief	9
Area 5		
80-251	Modern Philosophy	9
80-252	Kant	9
Area 6		
80-521	Seminar on Formal Epistemology: Belief and Evidence	9
80-261	Experience, Reason, and Truth	9
80-271	Mind and Body: The Objective and the Subjective	9

Additional Major

Students who wish to pursue an additional major in Philosophy must fulfill the same departmental requirements as primary majors in Philosophy. Students can double count any course for the major with another major or minor.

The Master of art in Philosophy

The Philosophy M.A. (https://www.cmu.edu/dietrich/philosophy/graduate/masters/philosophy/) provides exciting opportunities to pursue postgraduate studies in Philosophy for students with a degree in Philosophy who wish to continue their work in a more focused and advanced way, as well as for students with a degree in another field who wish to add a concentration in Philosophy. Students in this program will develop an understanding of a wide variety of philosophical subfields. The flexible course of study can be tailored to a student's interests and background. Students are expected to complete a Master’s thesis by the end of their second year, though a purely course-based option is also available for students who do not wish to continue in academia.

The course of study for the 5 (https://www.cmu.edu/dietrich/philosophy/graduate/5th-year-masters.html)th year M.A. in Philosophy is very flexible, and can be tailored to a student's interests and background. For more information, please contact the Academic Program Manager.

Philosophy Department Minors

The Philosophy Department offers six minors, and the requirements are designed to be flexible and to allow students to tailor courses to their special interests, while providing some breadth.

- Ethics
- Linguistics
- Logic & Computation
- Philosophy
- Rationality, Uncertainty, and Choice: Formal Methods (RUC)
- Societal & Human Impacts of Future Technologies (SHIFT)

The Minor in Ethics

The Minor in Ethics introduces students to central ethical concepts and theories proposed and defended by the great philosophers of the past; it provides an understanding of how these theories and concepts can be applied to practical problems. This background in ethical theory and its applications should help students to respond more sensitively and appropriately to the new and unavoidable ethical problems that technologies, businesses, unions, and branches of government must face.

Ethics minors must complete five philosophy courses in the areas listed below. All five required courses must be taken for a letter grade and passed with a grade of a "C" or above, except 80-500 Undergraduate Internship, which may be taken pass/fail.

Ethics Core Courses 27 units

Complete three courses from any of the following areas with at least two courses at the 200-level or higher.

		Units
80-130	Introduction to Ethics	9
80-135	Introduction to Political Philosophy	9
80-136	Social Structure, Public Policy & Ethics	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-246	Moral Psychology	9
80-249	AI, Society, and Humanity	9
80-330	Ethical Theory	9
80-335	Social and Political Philosophy	9
80-336	Philosophy of Law	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9

Ethics Electives 18 units

Complete two courses at the 200-level or higher. These courses may be additional courses from Ethics Core list above.

		Units
80-234	Race, Gender, and Justice	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-246	Moral Psychology	9
80-330	Ethical Theory	9
80-335	Social and Political Philosophy	9
80-336	Philosophy of Law	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9

The Minor in Linguistics

Linguistics is the scientific study of human language. The central goal of the Linguistics Program is to provide students with the analytical skills and linguistic concepts needed to understand language scientifically, whether formally, as researchers, or informally, as participants in daily linguistic interactions. The foundation of the Linguistics Minor is a set of rigorous core courses, informed by contemporary approaches to the study of linguistic form and meaning. The Core courses cover the principal domains of linguistic analysis: phonetics and phonology, syntax, and meaning. Students then move on to the Extended Core, which includes more advanced courses as well as courses on a wider range of topics, such as intonation and language variation. All courses counted towards the minor must be taken for a letter grade and passed with a grade of "C" or above.

Core (27 units)

Required		Units
80-180	Nature of Language: An Introduction to Linguistics	9

Select 2 from the following 3 options		Units
80-282	Phonetics and Phonology I	9
80-280	Linguistic Analysis	9
or 80-285	Natural Language Syntax	
80-381	Meaning in Language	9
or 80-383	Language in Use	

Extended Core: Choose 3 courses (27 units) from the Extended Core and/or additional courses from Core.

Extended Core		Units
80-283	It Matters How You Say It	9
80-286	Words and Word Formation: Introduction to Morphology	9
80-287	Language Variation and Change	9
80-288	Intonation: The Meaning of Linguistic Tunes	9
80-382	Phonetics and Phonology II	9
80-384	Linguistics of Turkic Languages	9
80-385	Linguistics of Germanic Languages	9
80-388	Linguistic Typology: Diversity and Universals	9
80-488	Acoustics of Human Speech: Theory, Data, and Analysis	9

The Minor in Logic and Computation

The Minor in Logic and Computation provides students with general course work in logic, the theory of computation, and philosophy. Students must complete six courses, among them the following three core courses. All courses counted towards the minor must be taken for a letter grade and passed with a grade of "C" or above.

Logic and Computation Core Courses — 27 units

		Units
80-150	Nature of Reason	9
80-211	Logic and Mathematical Inquiry	9
or 80-210	Logic and Proofs	
80-310	Formal Logic	9
or 80-311	Undecidability and Incompleteness	

Logic and Computation Electives — 27 units

Students must take two courses in the Philosophy Department at the 300-level or higher, in subjects related to logic and computation. And an additional course at the 300-level or higher in an area that uses logical and computational tools, such as philosophy, computer science, linguistics, mathematics, psychology, or statistics. The choice of electives must be approved by the Academic Program Manager.

The Minor in Philosophy

The Minor in Philosophy requires five courses and gives students a broad philosophical foundation, requiring one course in Logic/Methodology, two courses in the History of Philosophy and two Philosophy electives. The minor complements any primary major from around the University. All courses counted towards the minor must be taken for a letter grade and passed with a grade of "C" or above.

Logic/Methodology Requirements — 9 units

Complete one course:		Units
80-210	Logic and Proofs	9
80-211	Logic and Mathematical Inquiry	9
80-220	Philosophy of Science	9
80-221	Philosophy of Social Science	9
80-226	The Nature of Scientific Revolutions	9
80-310	Formal Logic	9
80-311	Undecidability and Incompleteness	9
80-312	Mathematical Revolutions	9
80-315	Logics for Knowledge and Belief	9
80-324	Philosophy of Economics	9
80-325	Foundations of Causation and Machine Learning	9
80-365	Ramsey	9
80-411	Proof Theory	9
80-413	Category Theory	9
80-514	Categorical Logic	9
80-516	Causality and Machine Learning	9
80-521	Seminar on Formal Epistemology: Belief and Evidence	9

History of Philosophy Requirements — 18 units

Complete two courses:		Units
80-150	Nature of Reason	9
80-226	The Nature of Scientific Revolutions	9
80-250	Ancient Philosophy	9
80-251	Modern Philosophy	9
80-252	Kant	9
80-253	Continental Philosophy	9
80-254	Analytic Philosophy	9
80-261	Experience, Reason, and Truth	9
80-350	Adam Smith	9
80-551	Seminar on History of Philosophy: Smith and Hume	9
80-358	Hume	9
80-365	Ramsey	9

Philosophy Electives — 18 units

Students must complete 18 units in the Philosophy department at the 200-level or higher. The choice of electives must be approved by the Academic Program Manager.

The Minor in Rationality, Uncertainty, and Choice: Formal Methods (RUC)

Students pursuing the minor in Rationality, Uncertainty, and Choice: Formal Methods (RUC) will learn interdisciplinary philosophical and mathematical approaches to reasoning about uncertainty and decision making in both individual and group contexts.

The RUC minor consists of three core requirements in **Game Theory, Decision Theory**, and a choice between the **Decision Analysis** and **Decision Models and Games** from the Department of Social and Decision Sciences. Students will then take 3 elective courses from two elective categories. Electives are intended to show how key concepts from the RUC core can be applied across many disciplines. The RUC minor uniquely complements majors from across Carnegie Mellon University and extends to fields such as economics and computer science. All courses counted towards the minor must be taken for a letter grade and passed with a grade of "C" or above.

Core Requirements

Complete all of the following:		Units
80-305	Game Theory	9
80-306	Decision Theory	9

88-223	Decision Analysis	12
or 88-312	Decision Models and Games	

Note: Students must complete three elective courses from the following two categories and must complete at least one course in each category.

Elective Category 1: Formal Foundations		9-18 units
80-201	Knowledge and Justified Belief	9
80-208	Critical Thinking	9
80-210	Logic and Proofs	9
80-315	Logics for Knowledge and Belief	9
80-325	Foundations of Causation and Machine Learning	9
80-516	Causality and Machine Learning	9
80-521	Seminar on Formal Epistemology: Belief and Evidence	9
80-524	Topics in Formal Epistemology: Topological Philosophy of Science	9
88-223	Decision Analysis	12
88-312	Decision Models and Games	9
88-379	Data-Driven Decision Analysis	9

Elective Category 2: Theory and Applications		9-18 units
80-246	Moral Psychology	9
80-249	AI, Society, and Humanity	9
80-252	Kant	9
80-255	Pragmatism: Making Ideas Work	9
80-261	Experience, Reason, and Truth	9
80-324	Philosophy of Economics	9
80-330	Ethical Theory	9
80-335	Social and Political Philosophy	9

The Minor in Societal & Human Impacts of Future Technologies (SHIFT)

Students pursing the SHIFT minor will gain the skills, knowledge, and experience to successfully take on roles in integrated, multidisciplinary analyses of current and near-future computational technologies. The SHIFT minor requires eight total courses, with no limit to double-counting with other majors or minors. All courses counted towards the minor must be taken for a letter grade and passed with a grade of "C" or above.

Core Courses (2 courses, 10 to 18 units total)		Units
80-249	AI, Society, and Humanity	9
80-445	Shift Capstone Experience	1-9

Area Courses (6 courses, 54 units total)
Note: Five of the six Area Courses must be taken in different departments

Technology area (18 units)
Courses that build basic technological competence, and teach concepts and frameworks that provide high-level understanding of computational technologies, including their possibilities and limits.

Complete two courses		Units
05-317	Design of Artificial Intelligence Products	12
05-318	Human AI Interaction	12
05-320	Social Web	12
05-452	Service Design	12
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
16-467	Introduction to Human Robot Interaction	12
17-303	Cryptocurrencies, Blockchains and Applications	9
17-313	Foundations of Software Engineering	12
17-331	Information Security, Privacy, and Policy	12
17-333	Privacy Policy, Law, and Technology	9
17-355	Program Analysis	12
36-202	Methods for Statistics & Data Science	9
67-250	The Information Systems Milieux	9
88-300	Programming and Data Analysis for Social Scientists	9

Social & Behavioral Sciences area (18 units)
Courses that teach the concepts and frameworks of social and behavioral sciences (e.g., economics, psychology, sociology), including methods and analyses such as experimental design and quantitative and qualitative data analysis.

Complete two courses		Units
05-413	Human Factors	9
17-224	Influence, Persuasion, and Manipulation Online	9
36-200	Reasoning with Data	9
70-311	Organizational Behavior	9
70-321	Negotiation and Conflict Resolution	9
70-341	Team Dynamics and Leadership	9
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
84-266	Research Design for Political Science	9
84-267	Data Science for Political Science	9
84-369	Decision Science for International Relations	9

Ethics, Policy & Design Area (18 units)
Courses that teach core concepts and frameworks to address and analyze ethical, policy, and design challenges relevant to current and near-future computational technologies.

Complete two courses		Units
05-413	Human Factors	9
08-200	Ethics and Policy Issues in Computing	9
16-161	ROB Seminar: Artificial Intelligence and Humanity	9
17-224	Influence, Persuasion, and Manipulation Online	9
36-200	Reasoning with Data	9
51-173	Human Experience in Design	9
51-241	How People Work	9
51-371	Futures I	4.5
51-373	Futures II	4.5
51-382	Design Center: Design for Social Innovation	9
70-311	Organizational Behavior	9
70-321	Negotiation and Conflict Resolution	9
70-332	Business, Society and Ethics	9
70-341	Team Dynamics and Leadership	9
70-364	Business Law	6
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
79-175	Moneyball Nation: Data in American Life	9
79-234	Technology and Society	9
79-302	Killer Robots? The Ethics, Law, and Politics of Drones and A.I. in War	9
80-130	Introduction to Ethics	9
80-135	Introduction to Political Philosophy	9
80-330	Ethical Theory	9
80-335	Social and Political Philosophy	9
84-266	Research Design for Political Science	9
84-267	Data Science for Political Science	9
84-275	Comparative Politics	9
84-319	Civil-Military Relations	9
84-325	Contemporary American Foreign Policy	9
84-369	Decision Science for International Relations	9
84-370	Nuclear Security & Arms Control	9
84-372	Space and National Security	9
84-373	Emerging Technologies and International Law	9
84-380	US Grand Strategy	9
84-386	The Privatization of Force	9
84-387	Remote Systems and the Cyber Domain in Conflict	9
84-389	Terrorism and Insurgency	9
84-390	Social Media, Technology, and Conflict	9
84-405	The Future of Warfare	9
88-221	Markets, Democracy, and Public Policy	9

Faculty

JEREMY AVIGAD, Professor of Philosophy – Ph.D., University of California, Berkeley; Carnegie Mellon, 1996–

STEVEN AWODEY, Professor of Philosophy – Ph.D., University of Chicago; Carnegie Mellon, 1997–

ADAM BJORNDAHL, Associate Professor of Philosophy – Ph.D., Cornell University; Carnegie Mellon, 2014–

CHRISTINA BJORNDAHL, Assistant Teaching Professor – Ph.D., Cornell University; Carnegie Mellon, 2014–

SIMON CULLEN, Assistant Teaching Professor – Ph.D., Princeton University; Carnegie Mellon, 2018–

ATOOSA KASIRZADEH, Assistant Professor of Philosophy – Ph.D., University of Toronto; Carnegie Mellon, 2024–

KEVIN T. KELLY, Professor of Philosophy – Ph.D., University of Pittsburgh; Carnegie Mellon, 1985–

ALEX JOHN LONDON, K&L Gates Professor of Ethics and Computational Technologies – Ph.D., University of Virginia; Carnegie Mellon, 2000–

KRZYSZTOF MIERZEWSKI, Assistant Professor – Ph.D., Stanford University; Carnegie Mellon, 2020–

AYDIN MOHSENI, Assistant Professor of Philosophy – Ph.D., University of California, Irvine; Carnegie Mellon, 2024–

JOSEPH RAMSEY, Special Faculty and Director of Research Computing – Ph.D., University of California, San Diego; Carnegie Mellon, 2006–

RICHARD SCHEINES, Professor of Philosophy, The Bess Family Dean's Chair of the Dietrich College of Humanities and Social Sciences – Ph.D., University of Pittsburgh; Carnegie Mellon, 1987–

TEDDY I. SEIDENFELD, Herbert A. Simon Professor of Philosophy and Statistics – Ph.D., Columbia University; Carnegie Mellon, 1985–

WILFRIED SIEG, Patrick Suppes Professor of Philosophy – Ph.D., Stanford University; Carnegie Mellon, 1985–

MANDY SIMONS, Professor of Philosophy – Ph.D., Cornell University; Carnegie Mellon, 1998–

JOEL SMITH, Distinguished Career Teaching Professor of Philosophy – Ph.D., University of Pittsburgh; Carnegie Mellon, 2000–

PETER L. SPIRTES, Professor of Philosophy, Marianna Brown Dietrich Professor and Head of Philosophy – Ph.D., University of Pittsburgh; Carnegie Mellon, 1987–

DANIELLE WENNER, Associate Professor of Philosophy – Ph.D., Rice University; Carnegie Mellon, 2013–

THOMAS WERNER, Associate Teaching Professor of Philosophy – Ph.D., Rutgers University; Carnegie Mellon, 2003–

WAYNE WU, Professor, Philosophy and the Neuroscience Institute – Ph.D., University of California, Berkeley; Carnegie Mellon, 2010–

FRANCESCA ZAFFORA BLANDO, Assistant Professor of Philosophy – Ph.D., Stanford University; Carnegie Mellon, 2020–

KUN ZHANG, Associate Professor of Philosophy – Ph.D., The Chinese University of Hong Kong; Carnegie Mellon, 2015–

KEVIN ZOLLMAN, Professor of Philosophy, Herbert A. Simon Professor of Philosophy and Social and Decision Sciences – Ph.D., University of California, Irvine; Carnegie Mellon, 2009–

Courtesy

FRANK PFENNING , Professor, Computer Science Department – Ph.D., Carnegie Mellon University ; Carnegie Mellon, 2002–

VINCENT CONITZER, Professor, Computer Science Department – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2022–

Special Faculty

DERRICK GRAY, Special Faculty – Senior Lecturer – Ph.D., Rice University; Carnegie Mellon, 2013–

MARIO GÜNTHER, Visiting Assistant Professor – Ph.D., Ludwig Maximilian University of Munich; Carnegie Mellon, 2024–

Emeriti Faculty

ROBERT CAVALIER, Teaching Professor (Emeritus) – Ph.D., Duquesne University; Carnegie Mellon, 1987–

CLARK GLYMOUR, Alumni University Professor of Philosophy (Emeritus) – Ph.D., Indiana University; Carnegie Mellon, 1984–

DANA S. SCOTT, Hillman University Professor of Mathematical Logic, Computer Science and Philosophy (Emeritus) – Ph.D., Princeton University; Carnegie Mellon, 1981–

Department of Philosophy Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

80-100 Introduction to Philosophy

All Semesters: 9 units
Even philosophers have a hard time explaining what exactly philosophy is. Instead of attempting a definition, one might instead list some of the questions philosophers try to answer. Like most other academic fields, philosophy has its own sub-disciplines, and each of these has its own questions it tries to answer. In this course, we will be looking at questions from several of these areas of philosophy, including: What is the mind? Do we have free will? What does the answer to that question mean for practices of reward and punishment? Is morality relative? What, if anything, is its connection to religion? How can I know the right thing to do? How can I know anything? This class isn't a historical introduction to philosophy, and we will be jumping around through history and subjects as we please, concerned only with interesting questions and good answers. As a whole, the course will strongly emphasize some of the basic skills of doing just about any kind of philosophy: how to recognize and understand arguments, how to evaluate them, and how to construct your own. As it turns out, these are skills you need to successfully navigate your way through just about any field of study and any career. This course will include a fair amount of writing, but you'll be getting lots of help from me, from your TA, and even from your peers.

80-101 Dangerous Ideas in Science and Society

Fall and Spring: 9 units
Do cancel culture and "wokeness" stifle free speech on campus? When should campus speakers be protested or disinvited? Should race be considered in college admissions? Should we use genetic engineering to create super-intelligent babies? Under what circumstances, if any, is abortion permissible? When, if ever, can a doctor kill a newborn baby or a dying patient? If we can in the future, should we end human aging, allowing people to live for thousands of years? Does civilian gun ownership make people safer, and if not, should it be allowed anyway? Is the case for defunding the police compelling? Should the United States open its borders to more immigrants? Has neuroscience shown that free will is an illusion? Could a digital computer become sentient? What is the probability that we are living in a computer simulation? Is it rational to believe in God in a world that contains so much suffering? These are some of the toughest, most pressing questions of current social, moral, and philosophical inquiry. Philosophers address them by producing intricate and often beautiful arguments. In this course, you will assess those arguments and produce your own. You will learn how to have challenging, productive, and respectful discussions across political and moral differences. You will learn to think like a philosopher - to strip an argument presented in prose to its essentials and plainly expose its structure. This course will improve the clarity and rigor of your own thinking and writing. It will put you in a position to make progress on hard questions like those mentioned above. And it will improve your ability to crisply convey your ideas - an ability that will serve you well not just in class, but also in daily life.

80-130 Introduction to Ethics

Fall: 9 units
Philosophical ethics, or moral philosophy, covers a lot of ground. It asks and tries to answer questions like: What's good in life? What matters? What should I (and others) do? How should I (and others) act? What kinds of things out there must be treated ethically? Do we have moral duties to (at least some) non-human animals? Is morality subjective? Are there actually any objective moral truths? Morally speaking, what (if anything) is the difference between killing someone, and simply letting them die? In trying to answer these questions (and others), we'll engage in some wonderfully weird thought experiments, class discussions, smaller group discussions, debates, etc. We'll study and critique several moral theories which try to explain and help guide our moral judgments, and we'll try to apply these theories to real-life moral controversies. Past classes covered topics including drug prohibition, abortion, euthanasia, and physician-assisted suicide. This is an introductory philosophy class, so you'll be learning how to read, critique, do, and write philosophy generally, not just ethics. Considerable time and effort, both in lectures and in recitations, will be spent helping you learn to recognize and evaluate philosophical arguments, as well as empowering you to create, improve, and defend your own arguments in class assignments.

80-135 Introduction to Political Philosophy

Spring: 9 units
At the heart of political philosophy lie fundamental questions such as: What constitutes a just society? How, and under what circumstances do individuals incur political obligations to a particular state? This course provides a systematic investigation of the way such questions are answered by dominant schools of liberal political theory, such as the social contract tradition, utilitarianism and libertarianism. Later we will introduce critiques from socialist, and feminist theorists. Readings are drawn from classic works by authors such as Plato, Hobbes and Locke, and from the works of more contemporary theorists like Rawls, and Nozick.

80-136 Social Structure, Public Policy & Ethics

Intermittent: 9 units
The course will consider ethical questions surrounding social structure and public policy. It will analyze the role of political institutions and individual citizens in dealing with some of the greatest challenges facing our world: Global health crises, the spread of (and threats to) democracy worldwide, and world poverty. Some of the questions we will consider include: Are developed countries obligated to ameliorate poverty by providing foreign aid? What is democratic governance, and what do democratic representatives owe to their constituents? Should wealthy nations and corporations assist in the fight against life-threatening diseases worldwide? The course uses ethical and political theory, case studies, and empirical evidence to consider these questions.

80-150 Nature of Reason

Spring: 9 units
This course provides an accessible introduction to the historical development of philosophical ideas about the nature of reasoning and rationality (with a focus on mathematics and the sciences), from ancient to modern times. The first part of the course traces the search for deductive methods for obtaining certain knowledge, starting with Aristotle and Euclid all the way to the work of Boole and Frege in the 19th century. The second part of the course considers the history of skepticism about empirical knowledge, covering Plato, Descartes, Pascal, and Hume, along with replies to skepticism in the works of Bayes and Kant. The third part of the course discusses theories of the nature of the mind and mental processes, culminating in the computational conception of the mind that underlies contemporary cognitive science.

80-180 Nature of Language: An Introduction to Linguistics

Fall and Spring: 9 units
Language is used to talk about the world or to describe it, but how do we go about describing language itself? Linguistics is the name given to the science of language, whose task it is to give such a description. The discipline of linguistics has developed novel tools for describing and analyzing language over the last two hundred years and in this course we learn what these tools are and practice applying them. Sub-areas of linguistics which we study include phonetics (the study of speech sounds), phonology (the study of sound systems), morphology (the study of parts of words), and syntax (the study of combinations of words). Furthermore, we highlight various respects in which language and linguistics intersects with societal issues. The methods of linguistics are useful in the study of particular languages and in the study of language generally, so this course is useful for students of foreign languages as well as those interested in going on to study language acquisition, psycholinguistics, sociolinguistics, philosophy of language, and computer modeling of language.

80-201 Knowledge and Justified Belief

Intermittent: 9 units
Knowledge acquisition is central to the university's mission. The sciences seek knowledge of nature. Statistics concerns methods for finding and establishing scientific knowledge. Machine learning concerns the automated generation of knowledge. Database theory concerns the maintenance of knowledge. But then what are knowledge, justified belief, truth, and evidence, and how do all of those concepts fit together? The branch of philosophy that studies those questions is called epistemology, which just means "study of knowledge". This class confronts the central epistemological questions. Topics include the analysis of knowledge and justification (what are they?), skepticism (the justifiability of beliefs that goes beyond the data available), and the relationship between knowledge and deductive logic (are the consequences of knowledge knowable?). The proposed answers involve a subtle interplay of logic, probability, causation, and counterfactual reasoning. The course is self-contained, so there are no prerequisites.

80-207 Philosophy & Literature: Tolkien, Lewis, and the Inklings

Intermittent: 9 units
Does literature simply "dress up," or even distort, the claims of reason? Or can literature illuminate certain truths that philosophy does not (or cannot) express? Tackling this "ancient quarrel" between the disciplines, this course explores the work of the Inklings, a group of early 20th century Oxford thinkers committed to a strong version of the thesis that literature can articulate, even "create," unique and irreducible kinds of truth and meaning. We examine the creative and philosophical work of the four principal members of the Inklings (C.S. Lewis, J.R.R. Tolkien, Owen Barfield, and Charles Williams) and take up their debates in the work of later scholars, such as Martha Nussbaum, Nathan A. Scott, Douglas Hedley, and Judith Wolfe. The first half of this course examines the philosophical writings of the Inklings on problems of ancient and modern philosophy alongside questions of literary genre and form. In the second half, we bring these philosophical frameworks to bear in close readings of some of the Inklings' most famous works, including The Chronicles of Narnia and The Lord of the Rings.

80-208 Critical Thinking

Intermittent: 9 units
This course is an introduction to practical reasoning. The course will contain an elementary introduction to concepts important for reasoning and decision making, such as validity, probability, and utilities. Students will extensively practice critically analyzing and evaluating a wide variety of arguments found in newspapers, magazines, and elementary accounts of scientific reasoning. In order to help students develop the skills to analyze and evaluate arguments, the course will introduce several software packages recently developed at CMU that help students diagram arguments and causal reasoning; these packages have been shown to improve students critical reasoning skills. In addition, students will learn about a wide variety of statistical, logical, psychological, and causal fallacies that are used to mislead people.

80-210 Logic and Proofs

All Semesters: 9 units
Logic and amp; Proofs is a web-based course and introduces students to central issues in modern logic. It is designed for individual learning with rich interactive environments and dynamic intelligent tutoring. The material is presented on-line, and most exercises are done on-line as well. Readings of historical and philosophical character complement the core content. This on-line course is supplemented, indeed given additional grounding, by weekly meetings in very small groups. There, we have collaborative reviews, substantive discussions and critical reflections. The central question of the course is this: How can we analyze the structure of rational discourse or, more specifically, the logical structure of argumentation? An answer to this question requires: (i) uncovering the logical form of statements; (ii) defining the correctness of logical steps; (iii) formulating inference rules for the logical forms; (iv) designing strategies for argumentation with the inference rules. The course takes these steps for both sentential and quantificational logic.

Course Website: https://oli.cmu.edu/courses/logic-proofs/

80-211 Logic and Mathematical Inquiry

Fall: 9 units
Since ancient times, mathematical arguments have served as a paradigm for rational inquiry. We will study fundamental mathematical concepts and informal proofs as they occur in everyday mathematics. We will also use the methods of mathematical logic, which provides formal symbolic languages, to help us understand the structure of a mathematical argument. Finally, we will make use of a new computational "proof assistant," called Lean, to develop fully rigorous, machine-checked proofs.

80-212 Arguments and Logical Analysis

Intermittent: 9 units
Are there rational methods that can further our knowledge? The notion of rational inquiry presupposes that there are appropriate methods for the pursuit of knowledge. In this course, we will investigate the means by which a successful argument justifies its conclusion, as well as various subtle ways in which other arguments fail. The course will explore the use of logic as an instrument in the study of arguments and reasoning, and it will serve as a gentle introduction to the elementary concepts of formal logic. We will take a historically informed approach to studying logic and argumentative fallacies, and we will discover that logical tools and methods are useful for constructing and analyzing arguments in all disciplines, from philosophy and history to psychology and physics. Our goals are to acquire a solid grasp of some fundamental tools of modern logic, and learn how to use them to make our thinking and writing clearer, more precise, and more critical. To this end, our coursework will consist in homework and exams on topics in logic, as well as writing assignments on a variety of topics. This course is intended for students from any discipline who would like to improve their writing and critical thinking skills, as well as students who are interested in learning logic without having had prior contact with the subject.

80-220 Philosophy of Science

Intermittent: 9 units
In this course, we will examine some historical case studies (e.g., the Copernican revolution in astronomy) against which we will assess views pertaining to the significance, justification, and production of scientific knowledge. For example, should scientific theories be understood literally or as computational devices for deriving new predictions? How can universal conclusions ever be justified by a finite data set? Does explanation contribute to a theory's confirmation by the evidence? Does science aim to find the truth? Is probability in the world or only in our minds? Is explanation a matter of finding causes or are causes whatever it is that explains? Is scientific rationality objective or culture-relative?

80-221 Philosophy of Social Science

Spring: 9 units
This course will explore numerous philosophical issues that arise in the practice of various social sciences. One central question of the course is whether we can use traditional scientific reasoning to understand social phenomena, e.g. social inequalities, violence, changes in politics, discriminary practices, ecnomic forcasting, etc. in the same way that we use them to understand natural phenomena, e.g. gases, organisms, protein structure, and planetary orbits. Some of the more specific questions we address are: Because humans possess free will and act with intentions while light rays and planets in motion do not, are we forced to use different kinds of explanations in the two cases? How can we explain social institutions that depend upon cooperation when there considerable pyschological evidence that cooperation doesn't help us in achieving our own personal goals? Whereas natural scientists actively conduct experiments, social scientists can often only collect statistical and qualitative data. Does this difference prevent social scientists from inferring causal relations and laws of social behavior? Is our understanding of social phenomena always value laden given that values are an inherent aspect of social life?

80-226 The Nature of Scientific Revolutions

Fall: 9 units
Science is an ever-changing enterprise. Most scientific advances, though significant, occur within a stable framework of accepted theories and data. A few episodes of change in the history of science involve discarding and replacing fundamental theories of the world. These are often accompanied by significant changes in the vocabulary in which those theories are expressed, the tools used by scientists, the phenomena on which scientists focus, and the kinds of explanations they consider acceptable. A very small number of these episodes change the way humanity views its ability to know the natural world and its place in the universe. The latter two kinds of change in science have often been called "scientific revolutions." We will focus on three such radical transformations: The "Copernican Revolution" (or "the Scientific Revolution") of the 16th and 17th centuries, the Darwinian revolution of the 19th century, and the quantum revolution of the late 19th and 20th centuries. This course has two intertwined components: history of science and philosophy of science. In the historical component, we will examine in some detail the three major scientific revolutions. The philosophical components will help us understand the reasoning involved in scientific theory change. This course does not require detailed knowledge of any of the sciences used in examples of revolutionary change.

80-234 Race, Gender, and Justice

Intermittent: 9 units
Race and gender, along with their interfaces and interactions with such other social identities as sexuality, (dis)ability, and class, structure our experience of almost every aspect of our social and political reality. Philosophers approach these kinds of social identities from a variety of perspectives. They ask what these kinds of social categories really are, what they mean for the ways we live our lives and the ways we perceive and understand the world, how they have (mis)informed our theoretical and practical understanding of the nature of justice and political power, and what is owed to those affected by racial and gendered injustice. This course explores these topics, drawing on tools and perspectives from epistemology, ethics, and especially social and political philosophy.

80-244 Environmental Ethics

Fall: 9 units
In this class, we'll try to figure out what obligations we might have to the natural environment and the non-human living beings within it, as well as what justice requires of us in our use of natural resources given the needs of other human beings. Among other things, we'll spend considerable time on animal ethics: What moral obligations do we have to non-human animals? Is it morally OK to eat them? Does a dog count (morally speaking) as much as a human? Does a factory-farm chicken count as much as a wild endangered tiger? Then, given that many of the most pressing environmental problemslike climate changeare collective action problems, we'll consider why these problems are so sticky, what obligations we have as individuals in dealing with these problems, and what a just collective solution might look like. To that end, we'll examine the processes fueling climate change, we'll look at who is responsible for these processes, and we'll try to determine whether any current proposal to deal with climate change is an effective, just response to the problem.

80-245 Medical Ethics

Spring: 9 units
This course provides a detailed introduction to core ethical issues in medical ethics and public policy. Topics include: the moral responsibilities of health care providers to patients and various third parties such as the government or insurance companies, the status of health as a social good, questions of justice in access to health care, and questions of individual liberty and social responsibility at the ends of life including issues such as cloning, abortion, physician assisted suicide, and the definition of death. We will also examine specific ethical issues in the conduct of medical research and look at the impact of technological innovation on our notions of health, disease, life, death, and the family. While the course engages such substantive ethical issues it also attempts to sharpen students' skills in practical reasoning through argument analysis, analogical reasoning, and the application of theory and principles to particular cases.

80-246 Moral Psychology

Intermittent: 9 units
In this course you will read cutting-edge scientific work on morality and you will learn to interpret it in light of recent lessons from biology and computer science. This course will also introduce you to distinctions that philosophers have found useful for moral-psychological and meta-ethical theorizing. Topics that we may discuss include: the psychology of normative ethics; moral emotions (e.g., disgust, guilt, shame, pride, etc.); the origins of morality in human and nonhuman animals; moral development in babies and children; the role of moral judgment in folk theorizing; and mathematical models of morality inspired by insights from machine learning. However, this course is exploratory and designed to be open-ended. I hope and expect that students will help to determine what we read and discuss.

80-249 AI, Society, and Humanity

Fall: 9 units
AI and robotic technologies are developing rapidly and are increasingly incorporated into decisions, practices, and activities that impact individual and social interests. To ensure that these technologies advance meritorious goals without undermining important values or relationships, stakeholders must be able to understand the diverse ways in which new technologies can impact the lives of individuals and communities, the diverse dimensions on which such impacts can be evaluated and measured and where in the lifecycle of product development these various impacts might be anticipated and addressed. Through a series of case studies of current or near-future AI and robotics technologies students in this course will explore frameworks for assessing, evaluating and regulating novel technologies with the goal of ensuring that they support and advance human interests and social values.

80-250 Ancient Philosophy

Fall: 9 units
This course will cover Ancient Greek philosophy from the pre-Socratics to the later Hellenistic writers. We will prepare the background for Socrates and Plato by studying major Presocratic philosophers such as the Milesians, Heraclitus, and Parmenides, and then dive in to a careful study of some of the central works of Plato and Aristotle. A key theme of the class will be the way in which Socrates, Plato, and Aristotle sought to define philosophy in opposition to sophistry, and how the lessons learned from their confrontation with sophistry informed their ethical and metaphysical thought. The final sections will discuss post-Aristotelian movements such as Epicureanism, Skepticism, and Stoicism.

80-251 Modern Philosophy

Spring: 9 units
This class will focus on the history of Western philosophy in the modern period, with special emphasis on the "early modern" era of roughly 1600-1800. Massive upheavals and conflicts in science, politics, and religion fueled attempts to find new ways of making sense of the world, and we will try to situate our philosophers within this rapidly evolving intellectual context. In particular, we will examine the impact of these changes on two subfields of philosophy: metaphysics (the study of the nature of reality, distinguishing it from mere appearance), and epistemology (roughly, the study of knowledge itself). We will ask, and attempt answers for, questions like: What is knowledge, can we achieve it, and if so, to what extent? To what extent, if any, can our most basic scientific instruments, the human senses, lead us to the true nature of the world? These questions will unavoidably send us down paths into other subfields, like philosophies of mind, of free will, of ethics, and of religion. After reading early modern philosophers like Ren and #233; Descartes, Princess Elizabeth of Bohemia, John Locke, David Hume, and Immanuel Kant, we will turn to some more recent work in the modern and contemporary eras to see what lessons (if any) were learned, and what new approaches (if any) have been taken in the quest for knowledge and reality.

80-252 Kant

Intermittent: 9 units
Immanuel Kant was a CMU sort of person. He was an enthusiastic follower of Isaac Newton, and his approach to fundamental philosophy was: "what would robotics be like from the viewpoint of the robot?" From that starting point, he investigated what would have to be the case for the robot to know anything about its environment. The resulting "critical philosophy" defined the relevant philosophical vocabulary for generations of prominent mathematicians and scientists into the 20th century, and is pivotal background both for both the "analytic" and the "continental" schools of philosophy. This course starts with essential background reading in pre-Kantian, early modern sources, including Descartes. Then it focuses on a detailed reading of Kant's Critique of Pure Reason and related texts. Course requirements include written answers to reading questions and two short paper projects. There are no prerequisites.

80-253 Continental Philosophy

Intermittent: 9 units
This course provides students with an overview of key movements in European Philosophy. The historical background covers Descartes, Kant, Kierkegaard, and Nietzsche. The central tenets of phenomenology and existentialism (e.g., intentionality, Being-in-the-World, Bad Faith) will be discussed in the context of selected works from Husserl, Heidegger, Sartre and Merleau-Ponty. The course will conclude with the background for and current work of Habermas.

80-254 Analytic Philosophy

Intermittent: 9 units
This course examines the revolutionary impact of philosophy at the turn of the 20th century on contemporary thought and progress. By the 1920s some scientists and philosophers became hopeful that the end of the long tradition of philosophical deadlock was finally within reach. Buoyed in particular by Einstein's theory of relativity and the invention of modern logic, they created a new kind of philosophy with the goal of applying logical and empirical methods to philosophical problems. This new approach led to new puzzles and paradoxes, along with a focus on the age old question of what can be known and what is meaningful. The modern fields of linguistics, cognitive science, and information and computer sciences all owe a debt to these sources, as does of course contemporary philosophy. Our quest will be to understand both what authors like Frege, Russell, and the Vienna Circle were up to in the first place, and how their work contributed to the world we live in today.

80-255 Pragmatism: Making Ideas Work

Intermittent: 9 units
American Pragmatism represented an energetic attempt to bridge the divergent cultures of science and the humanities. The movement's founder, C.S. Peirce, was trained in chemistry and worked as a physicist, but he was also deeply concerned with the contemporary philosophical portrayal of science, which distinguished sharply between theoretical knowledge and practice. Peirce responded by constructing a comprehensive philosophy emphasizing the scientific importance of community, fallibility, and action. Pragmatism was developed and popularized by William James, who aspired to be a painter and ended up as an acknowledged founder of modern empirical psychology. James extended Peirce's position by defending the role of values in even the purest of empirical sciences. John Dewey, who is also well-known for his role in education, interpreted science as an evolving social system and developed a theory of aesthetics based on what we now call the psychology of problem solving. The pragmatists made lasting contributions to modern statistics, logic, and social science and their emphases on community, fallibility, action, and value in science are still of primary importance in philosophy and in the ongoing dialogue between the scientific and humanistic cultures.

80-261 Experience, Reason, and Truth

Intermittent: 9 units
A central issue in Western philosophy has been whether reason or experience (or some of both?) provides the foundations for human knowledge. This course explores that question by looking at various "empiricist" vs. "rationalist" debates from the 17th century to the present day. We will focus on the problems encountered in trying to give an adequate account of the our knowledge of the external world, the structure of our minds, and the nature and limitations of human knowledge. The scope of our investigation will extend to the nature of mathematical knowledge, to "thought experiments" in both science and philosophy, and to "nativism" vs. "empiricism" issues in contemporary cognitive science and moral theory. The course has two main goals: (1) to study key metaphysical and epistemological issues surrounding the nature of human knowledge and (2) to help improve our analytical and critical skills by extracting and evaluating various relevant philosophical arguments.

80-270 Problems of Mind and Body: Meaning and Doing

Fall: 9 units
Central to our existence is meaning and our responses to it. We believe and desire things and on the basis of these attitudes, we make things happen. How can meaning exist in a seemingly mindless world? How can the world give rise to a mind capable of agency?This course tackles the mind body problem in respect of explaining meaning and human action. We tackle philosophical problems with serious engagement with empirical work from psychology and neuroscience. Students taking the course will tackle these problems with emphasis on developing analytical abilities.

80-271 Mind and Body: The Objective and the Subjective

Fall: 9 units
This course is about the subjective and the objective. "Subjective" captures the distinctive features that characterize what it means to be a psychological subject. This includes the power to represent, to think, feel, sense and in general to be conscious. Subjective features seem radically different from the physical world of matter and forces, a world that seems meaningless, unthinking and nonconscious. How can the subjective be rooted in the objective? We address this central philosophical problem by engaging philosophy with science. In this course, we will investigate thinking, sensing, imagining, dreaming, hallucinating, mindfulness and self-knowledge. As a result, we will explore how the subjective might be the objective. Students will develop analytical techniques such as conceptual analysis and argument analysis.

80-275 Metaphysics

Intermittent: 9 units
The topical agenda of this course will vary. Typical topics include the problem of personal identity, the nature of human freedom, the nature of the self, the nature of reality and being, the nature of causality, and the question of whether solutions to such problems can be given. Classical as well as contemporary philosophic texts will be studied. For Spring 2011: Issues we will consider, in no particular order, include: Do properties exist? Why should you think there is an external world? What is a number? Why should you think other people have mental states? What are natural kinds? What constitutes the identity of things through time? What constitutes the identity of persons through time? What does determinism mean? Is there freedom of the will? What is possibility? What is necessity? Are there other possible worlds? When does one event cause another, and what does that mean? What could a deity be, and should you think there is one?

80-276 Philosophy of Religion

Intermittent: 9 units
Historically and cross-culturally, philosophy tends to emerge as an effort to understand religion. Whether or not one is a believer, religion can be viewed as a "stress test" of the concepts we bring to our understanding of the mundane world. Can we know that there is an infinite being behind mundane reality? What can we comprehend about such a being? Is morality prior to or subject to that being's will? Can such a being be innocent of our wrong-doing? If there is such a being, are we responsible for anything? All of those questions depend as much on what we mean by possibility, freedom and responsibility as they do on the truth of religion. In this class, we fearlessly confront those questions and, in the Carnegie Mellon spirit, we relate each philosophical reading to relevant issues in science and logic. Since the philosophy of religion literature focuses primarily on a Judeo-Christian context, the class begins with a short survey of the religious contexts of ancient Greece, Hinduism, and Budhism to provide points of reference from which to question Judeo-Christian presuppositions.

80-280 Linguistic Analysis

Spring: 9 units
How do physical events (sounds) or physical objects (marks on paper) create or transmit meaning? Linguistic values are assigned to sounds and marks, based on specific physical features, creating phonemes and graphemes. Juxtapositions of phonemes and graphemes create morphemes, minimal units that hold meaning, with syntax arranging morphemes into sentences, minimal units of information. Further structural changes change the mood of a sentence and give it new function - as a request for information, demand for action, presentation of alternatives, and so on. The goal of this course is to investigate the structure of basic sentences and then the changes to structure by which communicative function is realized. Building on material taught in Nature of Language, this course looks in detail at the syntax of human languages, taking into account cross-linguistic variety.
Prerequisite: 80-180

80-282 Phonetics and Phonology I

Fall: 9 units
This course aims to provide students with practical tools for the study of speech sounds. The first step in this analysis is isolating the speech sounds themselves, for any particular language. Following this, the relation between the articulatory features of sounds and their acoustic properties is examined using spectrograms and other devices. Basic phonological notions are covered, tracing their development in the twentieth century up through optimality theory. In optimality theory, contrast and allophonic variation are explained in terms of an input-output device which selects the most harmonic candidate still faithful to phonemes in the input. The course should be relevant not only to linguistics students, but to students of language generally, with applications to sociolinguistics, child language development, speech recognition technologies, and the study of foreign languages.
Prerequisite: 80-180

80-283 It Matters How You Say It

Spring: 9 units
Why do languages give us multiple ways to say the same thing? Given that in English we can say "My dog ate my homework," why do we sometimes prefer "My homework got eaten by my dog"? Why do we sometimes choose to refer to someone with just a pronoun ("he"), and sometimes choose their full name ("Charles Dickens")? What's the difference between telling someone: "This expensive coffee is tasteless," or telling them: "This tasteless coffee was expensive"? This course is about the choices that languages give us for conveying a particular message, and the communicative effects of those choices. We will see that it is both the words you use and the way you put them together that determines the total communicative effect of your utterance. While the course will focus on English, students will have an opportunity to work on another language of interest in their final project.

80-285 Natural Language Syntax

Spring: 9 units
This course regards modern linguistics as a set of powerful tools for understanding and using language, and among all the subfields of linguistics, syntax as one of the most powerful. There are, however, many approaches to syntax so how should one choose which syntax to study? In 1957, Chomsky published Syntactic Structures, building on earlier research but at the same time providing a novel approach to age-old problems in linguistics, particularly the productivity problem and the learning problem. (How do speakers produce and understand novel sentences, and how do children learn without being taught?) While it is true that the field has progressed far since 1957, Syntactic Structures still stands out for its simplicity and usefulness. In this course we look at how more recent developments in syntax can be reconciled with this earlier approach. Particular focus is on how students can use syntax, in learning other languages and in refining their own use of language.
Prerequisites: 80-180 or 80-284

80-286 Words and Word Formation: Introduction to Morphology

Fall: 9 units
How many words do you know? Is 'gonna' one word or two? How many meanings does 'unlockable' have? If someone can be 'inept', why can't they be 'ept'? In this course we study the lingusitics of words and word formation, known as morphology. We begin by asking what a word is, about the internal structure of words, and how new words are formed. Throughout, we will consider these questions from a cross-linguistic perspective, looking at morphological data from a wide range of languages. We will also consider how morphology interacts with other subfields of linguistics, including phonology, syntax and semantics. Finally, we will survey morphological questions from the perspectives of language acquisition, psychology, and cognitive science.
Prerequisite: 80-180

80-287 Language Variation and Change

Spring: 9 units
We all know that languages differ and change, and that even two people who know the "same" language can sound quite different to each other, use different words, or even different sentence structures. This course takes students on a tour through linguistic difference across languages, within languages, and over time. We will look at how historical linguists reconstruct dead languages, how sociolinguists model language change, and how linguistic typologists assess whether some linguistic features (e.g., word order) are more or less common than others. We will also explore how linguistic variation and change are related to issues of social status and political power, and we'll investigate explanations for variation and change, drawing on literature from computational modelling and psycholinguistics. There is no prerequisite, and no prior linguistic knowledge is assumed.

80-288 Intonation: The Meaning of Linguistic Tunes

Spring: 9 units
Intonation is the melody of speech: how a speaker's pitch changes over the course of an utterance, along with the placement of emphasis, or sentence-level stress. Intonation and stress contribute to the interpretation of utterances in multiple ways. For example, the questions "Did BOB go to the store?" and "Did Bob go to the STORE?" contain the same words, but request different information. Similarly, whether the sentence "Bob went to the store" is interpreted as a statement or as a question, and whether as expressing certainty or uncertainty on the part of the speaker, depends on its intonation. Features of intonation can also convey information about the speaker's attitudes and affect: sarcasm and irony, for example, may be signaled by intonation. The goal of this course is two-fold. First, students will learn about the phonetic correlates of intonation and stress, and learn how to analyze intonation as a system of high and low tones, using the intonation transcription system ToBI. This will enable students to accurately describe the intonation pattern of an utterance. Second, students will learn how intonation is used to convey semantic and pragmatic information. The course will focus primarily on English, but other languages will be explored to serve as a basis of comparison. The course will be of interest to students interested in learning some of the intricacies of face-to-face linguistic communication. Students in the departments of English, Modern Languages, Language Technology, Human-Computer Interaction, and Psychology will find material relevant to their major topics. The course serves as an elective for the Linguistics Major, and is a natural companion to other courses on the expression of linguistic meaning: Meaning in Language, Language in Use, and Syntax and Discourse. The course requires basic background in phonetics.
Prerequisites: 80-283 or 85-385 or 80-488 or 80-180 or 80-284

80-305 Game Theory

Fall: 9 units
Game theory is the study of interactive decision-making: making choices in the context of other agents who are also making choices. Famous examples include the Prisoner's Dilemma (pitting rational self-interest against the benefits of cooperation), and the Cournot duopoly (a basic model of market competition and supply-and-demand). Game theory has been applied to situations as diverse as traffic flow, auctions, the search and competition for scarce resources, and bargaining. This course will develop conceptual and technical facility with the mathematical tools used to model and analyze such situations. We will cover both simultaneous and sequential games and become familiar with a variety of concepts such as strict and weak dominance, randomization, expected utility maximization, never-best responses, non-credible threats, and time discounting. We'll also study solution concepts such as Nash equilibrium, correlated equilibrium, rationalizability, and subgame perfect equilibrium. Throughout the course we will take the opportunity to actually play several of the games we study to help build intuitions and foster insights into the formal mathematical models we develop. Some experience with mathematical methods (definitions, proofs, etc.) will be helpful.

80-306 Decision Theory

Spring: 9 units
This course is an introduction to formal models of choice and decision-making. We begin by examining choice under certainty, developing both qualitative and quantitative models of preference. We then expand our analysis to take into account uncertainty, focusing on the von Neumann-Morgenstern theory of expected utility and Savage's classic axioms. Empirical challenges to models are emphasized throughout, in response to which we will consider a variety of alternative representations of uncertainty (e.g., Dempster-Shafer belief functions, non-unique probability measures) and preference (e.g., framing effects, prospect theory).

80-310 Formal Logic

Fall: 9 units
Among the most significant developments in modern logic is the formal analysis of the notions of provability and logical consequence for the logic of relations and quantification, known as first-order logic. These notions are related by the soundness and completeness theorems: a logical formula is provable if and only if it is true under every interpretation. This course provides a formal specification of the syntax and semantics of first-order logic and then proves the soundness and completeness theorems. Other topics may include: basic model theory, intuitionistic, modal, and higher-order logics.
Prerequisites: 21-127 or 15-251 or 80-210 or 80-211

80-311 Undecidability and Incompleteness

Spring: 9 units
U and amp; I focuses on two fundamental results: the undecidability of logic (established by Alonzo Church and Alan Turing) and the incompleteness of mathematical theories (discovered by Kurt G and #246;del). The proofs of these results require a novel metamathematical perspective, but also striking logical concepts and fascinating mathematical techniques. In this course, the theorems are not just formulated but actually proved. We begin with the axiomatic development of elementary set theory that allows, at the same time, the formal representation of informal mathematics like number theory. With this basis, one can show that syntactic notions concerning set theory are representable in the very theory. It is then easy to prove that set theory is incomplete. To show that logic is undecidable, the crucial concept of computation is introduced via Turing machines. The two central concepts - proof and computation - are fundamental for mathematics, computer science and, in particular, artificial intelligence. The undecidability and incompleteness results are among the most significant contributions of modern logic to the foundations of mathematics. They provide also the beginnings of a deeper understanding of mental processes in cognitive science and, thus, of the human mind. To understand the latter connections, we will read about and discuss historical as well as philosophical aspects of the subject.
Prerequisites: 15-251 Min. grade C or 80-211 Min. grade C or 80-210 Min. grade B or 21-300 Min. grade C or 80-310 Min. grade C

80-312 Mathematical Revolutions

Spring: 9 units
Mathematics is a central part of our intellectual experience. It is connected to sophisticated philosophical perspectives, say, in the work of Plato, Descartes, Leibniz, Kant, as well as in contemporary analytic philosophy; it is equally connected to fundamental views in the sciences, say, in the work of Ptolemy, Galileo, Newton, Einstein, as well as in contemporary cosmology. The common view that mathematics - if not directly "static" - is evolving in a linear fashion, does not withstand historical scrutiny. Indeed, there are many dramatic conceptual changes concerning the very nature and object of mathematics.

80-315 Logics for Knowledge and Belief

Fall: 9 units
Standard logical languages can express negation ("not p"), conjunction ("p and q"), material implication ("if p then q"), quantification ("for all x, p(x)"), etc. But they don't directly capture statements like the following: "Alice knows p." "Henceforth, it will be the case that p." "It ought to be the case that p." "If it had been the case that p, it would have been the case that q." "Everybody knows p." "Everybody knows that everybody knows p." "Infinitely often in the future, p will be true." "After an announcement of p, it will be the case that Alice knows q." "If p is not permitted, then you ought to know that p is not permitted." etc. Modal logic is a very general framework for systematically reasoning about statements like these. This course is an introduction to mathematical modal logic and its applications in philosophy, computer science, linguistics, and economics, with emphasis on epistemic interpretations (i.e., logics for representing and reasoning about knowledge/belief). We begin with a rigorous development of propositional modal logic: the basic language, interpretation in relational structures, axiom systems, proofs, and validity. We prove soundness and completeness of various systems using the canonical model method and study model equivalence and expressivity results. We also consider topological semantics as an alternative to relational semantics, and investigate the connection between the two. In the latter part of the course we turn our attention to more specialized logical systems and their applications, as determined by the interests of the class. Topics may include: quantified modal logic, multi-agent systems and the notion of common knowledge (with applications to game theory), temporal and dynamic logics for (nondeterministic) program execution, logics for reasoning about counterfactuals, public announcement logic, deontic logic, intuitionistic logic, and others.
Prerequisites: 15-251 Min. grade C or 80-211 Min. grade C or 21-127 Min. grade C or 21-128 Min. grade C or 80-212 Min. grade C or 80-210 Min. grade C

80-316 Logic and AI

Intermittent: 9 units
In this course, we will study logical systems that are relevant to, and motivated by, research in artificial intelligence. We will see how key ideas and advances in logic have found (and continue to find) natural applications in AI. More generally, we will see how logic and AI can benefit, and historically have benefited, from each other. A central aim of this course is to understand how logical languages of varying expressive power can be put to use in AI as a tool for representation and reasoning. Some of the topics that we will be focusing on are (1) non-monotonic and default logics, (2) modal logics for reasoning about knowledge/belief, temporal structures, and computation, (3) probabilistic logics (and the relation between logic and probability), (4) logics of graphical causal models and counterfactuals, as well as (5) elements of probabilistic programming and computable probability theory.
Prerequisites: 80-610 or 80-310

80-324 Philosophy of Economics

Intermittent: 9 units
The science of economics has come to occupy a central position in contemporary society. Because of this central position in political decision making, economics is intertwined with a number of other philosophical issues surrounding justice, rights, and fairness. The central theme of this course will be on the arguments in favor and against markets as effective solutions to political problems. This issue will allow us to analyze a wide number of foundational issues in economics including the testability of economic claims, the use of "rationality" postulates, the foundation of the right to property, and measuring the success or failure of an economy.

80-325 Foundations of Causation and Machine Learning

Fall: 9 units
How can we define causality? Does smoking cause cancer? Can one find causality from observational data without temporal information? In our daily life and science, people often attempt to answer such causal questions for the purpose of understanding, proper manipulation of systems, and robust prediction under interventions. In the past decades, interesting advances were made in machine learning, philosophy, statistics, and economics for tackling long-standing causality problems, and a number of researchers have been recognized with the Turing Award (to Pearl in 2012) the Nobel Prize (to Granger in 2003 and to Sims in 2011). This course is primarily concerned with historical and technical developments of modern causality research, focusing particularly on how to discover causality from observational data and how to infer the causal effect of one variable on another. Thinking more broadly, causal analysis is a particular branch of unsupervised multivariate analysis. Accordingly, this course also provides a big picture of the foundations of causation and unsupervised machine learning. We start with unsupervised learning and multivariate statistical analysis problems including factor analysis, principal component analysis, and independent component analysis, and formulate their assumptions, develop their solutions, and study their connections with causal analysis. Finally, we investigate how the causal perspective helps in solving advanced machine learning or artificial intelligence problems, including transfer learning, image-to-image translation, reinforcement learning, and unsupervised deep learning.

80-330 Ethical Theory

Spring: 9 units
This course provides a detailed survey of the structure of prominent theories of normative ethics. The space of possible consequentialist theories is surveyed in detail, allowing students to understand what distinguishes different forms of consequentialism and to assess the relative merits of these theories. The space of non-consequentialist theories is also surveyed, although in slightly less detail. The course engages classic texts from Aristotle, Kant and Mill and contemporary essays by leading philosophers.

80-334 Social and Political Philosophy

Intermittent: 9 units
Political philosophers are interested in whether, and to what extent, government use of coercion can be justified. This question involves many facets, including what gives the government the legitimate authority (if any) to coercively enforce the rules, what limits there are (if any) to the legitimate kinds of rules the government can enforce (and why), what obligations (if any) the government has to the citizens that are governed by its rules, and what claims (if any) citizens of a state can make upon one another. This course provides a systematic investigation of such questions as well as the concepts that are often appealed to in political theory, such as "justice," "equality," and "fairness." Readings will be comprised of classic and contemporary theorists from within the liberal political tradition as well as theorists critical of this tradition and its ability to live up to the lofty ideals it espouses.

80-335 Social and Political Philosophy

Fall: 9 units
Broadly speaking, political philosophers are interested in whether, and to what extent, government use of coercion can be justified, and how formal social and political institutions should be structured in order to be legitimate. Social philosophy encompasses these political questions, but also looks at how individuals should live together and how individual behaviors can impact not only state institutions but also more informal social norms and institutions. This is an advanced course in social and political philosophy, aimed at providing students with an in-depth familiarity with classic and contemporary questions both theoretical and applied.

80-336 Philosophy of Law

Intermittent: 9 units
In recent years, the U.S. legal system has been beset by claims of overcriminalization, racially discriminatory enforcement, and inadequate or unequal protection of individual civil rights. What should we make of these claims, and what, if anything, would be implied by their truth? In seeking to answer these questions, this course will examine the nature of the law and its enforcement. We will begin by discussing the issue of criminalization and whether the expansion of the criminal law is or is not problematic. From there, we will turn to the more foundational questions of what, precisely, the law is, and what its connection to morality is or should be. Are we obligated to obey the law, and if so, why? Finally, we will ask whether it is possible for the law to remain neutral with regards to morality and politics, and whether the supposed "neutrality" of the law may itself be an instrument of oppression. If the legal system lacks the kind of neutrality that many legal theorists claim for it, what (if anything) does that license us (as citizens) to do?

80-348 Health, Human Rights, and International Development

Fall: 9 units
Approximately 767 million people, or more than 10% of the world's population, live in a condition the World Bank refers to as "extreme poverty". Those who live in extreme poverty frequently lack effective access to proper nutrition, adequate shelter, safe drinking water, and sanitation. As a result, they also bear the greatest burdens of famine and epidemic disease and frequently face social and political conditions of unrest and systematic oppression. This course aims to introduce students to the problem of global public health and its intersection with claims of human rights. We will focus on theoretical accounts of human rights and questions arising from them: What constitutes a human right, and on what basis or bases might the existence of human rights be defended? If human rights exist, whose responsibility is it to see that they are defended/provided/not violated, and why? What is the relationship between health deficits and human rights deficits, and what would a "human right to health" look like? Are global institutions such as the protection of strong intellectual property rights consistent with respect for a human right to health?

80-350 Adam Smith

Intermittent: 9 units
Adam Smith is known as the father of economics. Many view Smith as a champion, not just of the science of economics, but of modern libertarian thought. His last book, The Wealth of Nations, is seen as the first defense of the value of free market capitalism. Less well known is Smith's earlier work which presents a altogether different picture. In it, Smith emphases the importance of altruism, empathy, and the value of interpersonal connection. In this course we will investigate the thought of Adam Smith, and find that he is far more complex than often portrayed.

80-358 Hume

Intermittent: 9 units
This course will investigate the philosophy of David Hume. We will focus on his philosophical thought expressed in the book A Treatise of Human Nature. Hume was an influential philosopher who wrote on many issues ranging from skepticism, to ethics, to the philosophy of science, and his views continue to be influential today. In this course we will attempt to understand Hume's philosophy on all of these subjects both to better understand his contribution to the philosophy of his day, but also to see what his arguments can contribute to contemporary thought.

80-365 Ramsey

Intermittent: 9 units
Frank Ramsey's untimely death in 1930, at the age of 26, marked the loss of a versatile and original thinker. During his short life, he made decisive and influential contributions to philosophy, mathematics and economics. The entire core of Ramsey's philosophical and scientific work consists of no more than 15 papers; in all cases they are remarkable essays that changed the intellectual topics they touched. This course will explore Ramsey's seminal contributions to probability and decision theory, philosophical and mathematical logic, the foundations of mathematics, metaphysics, and the philosophy of science. We will read some of Ramsey's original papers as well as more recent work inspired in response to, or as an elaboration on, Ramsey's views. We will see how Ramsey laid the foundations of the theory of subjective probability and decision theory, offered one of the first formulations of a deflationary theory of truth, and inspired contemporary work in philosophical logic (particularly on the logic of conditionals). We will explore Ramsey's influential work in the philosophy of science - his accounts of laws, causality, and the nature of scientific theories - as well as his mathematical contributions to logic and (what is now known as) Ramsey theory. By examining Ramsey's contributions and their impact, the course will give a sense of their important position as quintessential examples of work in the analytic tradition, demonstrating the intellectual fruitfulness of interdisciplinary inquiry into foundational questions and of mathematically informed philosophy.

80-381 Meaning in Language

Fall: 9 units
One of the more elusive topics in the linguistics of natural language is meaning. This is the field of semantics. A key question to answer in semantics is what meaning even is. In this course, we will give an answer to this question, starting with the meaning of basic sentences. These are sentences that describe what is the case. From there, we break sentence meaning into the meaning of words. In the other direction, we consider the meaning of non-basic sentences such as questions and imperatives. We also consider the meaning of complex sentences and sentences that express irrealis. That starts with the subject of negation, with sentences that describe what is not the case. From there we move to sentences used to talk about what could be the case, what will be the case, what could've been the case, and what could never have been the case. A peculiarity of semantics is that the abstract questions we ask yield answers that are highly concrete and practical. But that only makes sense given that language permeates every human activity and it really matters what we mean by what we say.
Prerequisite: 80-180

80-382 Phonetics and Phonology II

Spring: 9 units
One of the central questions of research in human speech is how the patterning of speech sounds (phonology) relates to the articulatory, acoustics, and perceptual (phonetic) properties of speech; this problem is often referred to as the "phonetics-phonology interface". In this course, students will act as co-investigators on a topic at the phonetics-phonology interface, carrying out an acoustic study to test hypotheses that are relevant to phonological research. As co-researchers, students will be involved in all aspects of data collection and analysis. Lessons in phonetics will be designed to train students on the necessary skills and concepts required, including understanding the phonetic correlates of the phenomenon under investigation, as well as data analysis and interpretation of the results. A presentation session will be organized for the end of the semester. In tandem with the phonetic study, related phonological phenomena will be investigated throughout the semester. Students will finish this course with a solid understanding of how to do phonetic research, and an appreciation of how various theoretical frameworks have attempted to account for phonological phenomena. Assessment will take the form of quizzes, take-home problem sets, reflections on the research process, and a final report and presentation.
Prerequisites: 80-180 and 80-282

80-383 Language in Use

Fall: 9 units
In ordinary conversation, what a speaker conveys by the utterance of a sentence may go beyond, or be quite different from, the meaning that could be assigned to the sentence or expression that they use without consideration of the context in which it occurs. For example, the sentence "I have homework" means one thing; but it conveys something more when uttered in answer to the question "Do you want to go see a movie tonight?" In this course, we explore how the systematic study of linguistic meaning can be expanded from the domain of the sentence to the domain of connected, multiparty discourse. This involves taking into account the contributions of context, and of speaker and hearer's beliefs, goals and intentions, to the construction of meaning. This course is one of the set of courses on language and meaning offered by the Program in Linguistics, including in addition to this: 80-283 It Matters How You Say It, 80-288 Intonation, and 80-381 Meaning in Language. Each of these courses can be taken independently; as a set, these courses provide a comprehensive introduction to contemporary approaches to natural language semantics and pragmatics.
Prerequisites: 80-100 or 80-180

80-384 Linguistics of Turkic Languages

Intermittent: 9 units
In this course we look at languages from within a single language group, Turkic. Turkic languages are spoken across continental Asia and include such languages as Turkmen, Tatar, Kazakh, Uighur, and Uzbek. In this course we concentrate especially on Yakut (Sakha) and Azerbaijani. Modern Turkish will provide a reference language. We look at various linguistic systems within each language (phonology, morphology, syntax, and writing systems) both to understand each particular language and to see how the languages are related. We consider the impact of diachronic factors on the synchronic study of language. This course can be seen as an extended case-study for applying concepts and analytical strategies from basic linguistics, as taught in Nature of Language, Phonetics and Phonology, Invented Languages, and other relevant courses.
Prerequisite: 80-180

80-385 Linguistics of Germanic Languages

Intermittent: 9 units
The Germanic languages include English, Dutch, Frisian, German, Pennsylvanisch, Afrikaans, Yiddish, Icelandic and the Scandinavian languages, excluding Finnish. The course will serve as an extended case-study for the application of concepts and analytical strategies taught in basic linguistics courses to some of these languages. Specifically, we take a bottom-up approach to Dutch, Frisian, Icelandic, and Danish, starting with raw language material whenever possible, which we progressively analyze in terms of phonetics and phonology, morphology, and syntax. These case studies lead to comparisons between the languages and insight into their development and divergence over time. We follow this hands-on approach with historical and grammatical overviews, touching on some of the outstanding issues in Germanic linguistics. The approach should also help bring out the relevance of diachronic factors in the synchronic study of language, with historical forms of English being open to investigation, as these often reflect patterns found in contemporary Germanic languages.
Prerequisite: 80-180

80-388 Linguistic Typology: Diversity and Universals

Fall: 9 units
What is the most common word order? What is the rarest consonant? What kinds of case marking are attested in the world's languages? Which linguistic structures tend to co-occur? What can we learn by looking at the rarity of linguistic structures? These are the kinds of questions central to linguistic typology, the study and classification of languages based on their structural properties. In this course we will look at the variety of linguistic structures attested in several linguistic subfields, including phonology, morphology, syntax, and semantics. Understanding linguistic diversity is closely tied with the search for linguistic universals, since there appear to be some ways in which linguistic structures seem to be limited. But what is the nature of those limits (if they truly exist), and what do they tell us? We will also look at methodological issues that arise in comparing languages and forming meaningful generalizations. Prerequisites: 80-180, and one of 80-280, 80-282, 80-285 or permission of the instructor.
Prerequisites: 80-180 and (80-280 or 80-285 or 80-282)

80-405 Game Theory

Spring: 9 units
Game theory is the study of interactive decision-making: making choices in the context of other agents who are also making choices. Famous examples include the "Prisoner's Dilemma" (pitting rational self-interest against the benefits of cooperation), and the "Cournot duopoly" (a basic model of market competition and supply-and-demand). Game theory has been applied to situations as diverse as traffic flow, auctions, the search and competition for scarce resources, and bargaining. This course will develop conceptual and technical facility with the mathematical tools used to model and analyze such situations. We will cover games in strategic and extensive form and games of perfect and imperfect information; we'll also study solution concepts such as Nash equilibrium and rationalizability. Finally, throughout the course we will take the opportunity to actually play several of the games we study to help build intuitions and foster insights into the formal mathematical models we develop.

80-411 Proof Theory

Intermittent: 9 units
An introduction to the general study of deductive systems and their properties. Topics include the natural deduction and sequent calculi; cut-elimination and normalization theorems; metamathematical properties of first-order logic and theories of arithmetic; and conservation theorems.
Prerequisites: 21-300 or 80-310 or 80-311

80-413 Category Theory

Fall: 9 units
Category theory is a formal framework devoted to studying the structural relationships between mathematical objects. Developed in the mid-20th century to attack geometrical problems, subsequent progress has revealed deep connections to algebra and logic, as well as to mathematical physics and computer science. The course emphasizes two perspectives. On one hand, we develop the basic theory of categories, regarded as mathematical structures in their own right. At the same time, we will consider the application of these results to concrete examples from logic and algebra. Some familiarity with abstract algebra or logic required.

80-419 Interactive Theorem Proving

Intermittent: 9 units
Interactive theorem proving involves using computational proof assistants to verify that mathematical proofs are correct, or to verify that hardware and software designs meet their formal specifications. This course uses a new interactive theorem prover, Lean, to explore this new technology and its logical foundations. We will study dependent type theory, a powerful and expressive language for representing mathematical objects, algorithms, and proofs. We will also consider automated methods that can be used in support of formal verification, including propositional, equational, first-order, and higher-order methods, as well as decision procedures for real and integer arithmetic.
Prerequisites: 21-300 or 15-317 or 80-310 or 80-211

Course Website: https://leanprover.github.io/theorem_proving_in_lean/

80-445 Shift Capstone Experience

Spring
The Societal and Human Impacts of Future Technologies capstone experience will be taken in either the fall or spring of the senior year. It is required for all SHIFT minors. The purpose of the capstone experience is for students to demonstrate learning over time within the minor. Key learning experiences include incorporating concepts, ideas, and amp; frameworks from multiple disciplinary perspectives, using disciplinary perspectives in appropriate ways, given their complementary strengths and amp; weaknesses, generating a multidisciplinary (2) of some current or near-future technology, collaborating with people of different disciplinary backgrounds, and communicating a single, integrated analysis of the impacts and amp; opportunities of this novel technology (and amp; recommended actions). SHIFT minors should work with the minor advisor during the Spring of their junior year to design an appropriate capstone experience.

80-447 Global Justice

Spring: 9 units
Until recently, the dominant view of international relations has been that the governments and citizens of one country have no moral obligations to those beyond their borders. With the rapid growth in globalization has come a drastic shift in attitudes about our obligations to those with whom we share global institutions of trade but neither legal systems nor national identities. This course aims to introduce students to the problem of global distributive justice in the context of a globalized world, with emphases on both theoretical accounts of justice and the practical implications of those accounts for important current issues. Theoretical topics will include the nature of justice, the sources and limits of our moral obligations, and how and whether those notions of justice extend to global society; while applied topics will include our obligations with regard to the environment, human rights deficits, the status of women, and global economic policy.

80-449 EHPP Capstone Course

Fall: 12 units
In this Fall 2023 capstone course, Ethics, History, and Public Policy majors will carry out a collaborative or individual research project that examines a compelling current policy issue that can be illuminated with historical research and philosophical and policy analysis. Students will develop an original research report based on both archival and contemporary data and present their results in a public forum at the end of the semester. Please note: this semester we are experimenting with a more flexible set of research options for EHPP students, rather than a single project topic that all students are required to work on. Collaborative projects in groups of 2-3 students are encouraged, but individual projects that integrate historical, ethical, and policy perspectives are permissible too.

80-484 Language and Thought

Spring: 9 units
The goal of this course is to provide students with the opportunity to creatively explore some difficult questions about the relationship between language and thought, questions such as: How does the human capacity to use language relate to the human capacity to think? Does the language that a person speaks affect the way she thinks? If meaning is in the head, how can we succeed in communicating with each other? How is our ability to reason related to our ability to successfully communicate? None of these questions have definite answers; throughout the course, we will draw on work in philosophy, psychology and linguistics to try to understand some of the possible answers that might be entertained. Students in the course should be prepared for extensive reading, writing and peer discussion assignments.

80-488 Acoustics of Human Speech: Theory, Data, and Analysis

Spring: 9 units
In this course, students will learn how to acoustically analyse human speech, and in so doing, will learn about both universal and language-particular acoustic characteristics of human speech. The class, which will comprise both lectures and a lab component, will introduce the basic principles of the physics of sound and how the source spectrum is modified by the vocal tract, but the focus throughout will be towards developing a solid understanding of how to perform the relevant analyses. Each week will introduce a new topic, chosen to exemplify a particular acoustic phenomenon. Lectures for that week will provide the theoretical basis for understanding the phenomenon, both in terms of acoustic theory and in articulatory terms. The lab for that week will provide students with relevant acoustic data to analyse using PRAAT, an open-source software used for acoustic analysis. Potential topics include: What does it mean to say someone speaks with "vocal fry", and how do we measure this? Why do children replace [r] with [w]? How can we compare sounds in two different languages? For example, what are the acoustic characteristics of [r] and [l] in English and Japanese, such that these sounds count as two different sounds in English, but are so similar in Japanese? What makes an [s] so noisy compared to an [f]? What happens to speech sounds when we talk quickly, or when we're sick and our nose is stuffed up? At the conclusion of the course, students will have a solid understanding of the acoustic characteristics of human speech, both in terms of the underlying theory and how to measure such phenomena. Further, they will be able to translate questions about speech into measurable acoustic variables. There is no prerequisite for this course. While technical material will be covered, no background in linguistics, acoustics, physics, or math is assumed, and all required skills will be taught as needed.

80-495 Independent Study

All Semesters
Undergraduate Independent Study Philosophy Department majors.

80-501 Undergraduate Research in Philosophy

Fall and Spring
This course is for students pursuing a research project under the supervision of a faculty member in the Philosophy Department. Time commitments as well as specific requirements, expectations, and deliverables of the research experience must be worked out in advance between the student and the supervising faculty member. The units can vary depending on the scope of the project.

80-514 Categorical Logic

Spring: 9 units
This course focuses on applications of category theory in logic and computer science. A leading idea is functorial semantics, according to which a model of a logical theory is a set-valued functor on a category determined by the theory. This gives rise to a syntax-invariant notion of a theory and introduces many algebraic methods into logic, leading naturally to the universal and other general models that distinguish functorial from classical semantics. Such categorical models occur, for example, in denotational semantics. e.g. treating the lambda-calculus via the theory of cartesian closed categories. Higher-order logic is treated categorically by the theory of topoi. We shall see how this idea connects logic with topology (the models of a theory form a space). A prerequisite for this course is familiarity with basic category theory (as treated in the course 80-413/713).
Prerequisite: 80-413 Min. grade C

Course Website: https://awodey.github.io/catlog/

80-516 Causality and Machine Learning

Fall: 9 units
In the past decades, interesting advances were made in machine learning, philosophy, and statistics for tackling long-standing causality problems, including how to discover causal knowledge from observational data, known as causal discovery, and how to infer the effect of interventions. A number of researchers have been recognized with the Turing Award (to Pearl in 2012) the Nobel Prize (to Granger in 2003 and to Sims in 2011). Furthermore, it has recently been shown that the causal view may facilitate understanding and solving various machine learning or artificial intelligence problems such as transfer learning, semi-supervised learning, disentanglement, and adversarial vulnerability. This course is concerned with understanding causality, learning causality from observational data, and using causality to tackle a class of learning problems. We will particularly focus on two key problems in causality. One is causal discovery. It is well known that "correlation does not imply causality," but we will make this statement more precise by asking what assumptions, what information in the data, and what procedures enable us to successfully recover causal information. Causal influences may take place between the underlying hidden variables, and what we measure may be their reflections; so we will also see how to find the underlying hidden "causal" variables as well as their causal relations by analyzing measured variables. Its implication in unsupervised deep learning will be discussed. The other is how to properly make use of causal information. This includes identification of causal effects, counterfactual reasoning, improving machine learning in light of causal knowledge, and forecasting in complex environments, and we will investigate how the causal perspective helps in domain adaptation, image-to-image translation, and deep reinforcement learning.

80-517 Seminar on Topics in Logic: Algorithmic Randomness

Intermittent: 9 units
What is randomness? One way to think about it is as a property of sequences of, say, events, experimental outcomes, observations, or symbols from some alphabet: a sequence is random if it is unruly, irregular, patternless. This conception of randomness plays a significant role in a variety of fields, including cryptography, information theory, the foundations of probability and statistics, computability theory, and certain computational models of learning. To build some intuition, consider the two binary strings 0010111110 and 0101010101. The first string seems more random-looking than the second. This is because the second string displays an obvious pattern that is very easy to describe and that makes it look highly predictable. But can these intuitions be made precise? Is it possible to provide a rigorous mathematical characterization of the notion of a random sequence? This seminar will provide an introduction to the theory of algorithmic randomnessan active branch of computability theoryaccording to which a sequence is random if it does not display any algorithmically detectable patterns. We will begin by discussing von Mises' theory of collectives, a precursor to the theory of algorithmic randomness; then, we will see how von Mises' work led to the modern computability-theoretic approach to randomness. We will focus on both the mathematical details of the theory of algorithmic randomness and its philosophical consequences. We will pay special attention to the connections between randomness, probability, and the philosophical interpretations of probability. Among the questions that we will address are: What is the relationship between probability and randomness? Is probability more primitive a concept than randomness, or is a precise analysis of randomness needed to understand what probabilities are? Is it possible to define "absolute" randomness? Does randomness have to satisfy any laws?

80-521 Seminar on Formal Epistemology: Belief and Evidence

Spring: 9 units
There has been a flurry of recent work on a variety of modal logics designed for reasoning about knowledge, belief, and evidence, in both static and dynamic contexts. What is the relationship between knowledge and belief? What is the role of evidence and justification? How do we react to new information, update our beliefs, and reason conditionally? These are old questions which modern logical frameworks promise to shed new light on. In this seminar we will read and analyze contemporary papers on these topics, both to gain an understanding of the current state-of-the-art, and to critically assess the extent to which these formal frameworks are genuinely enhancing our understanding of the underlying phenomena of interest.

80-524 Topics in Formal Epistemology: Topological Philosophy of Science

Intermittent: 9 units
When faced with a question concerning learning or scientific method, one habitually reaches for logic and probability theory. But sometimes habits should be questioned. There is increasing awareness, scattered across philosophy, informatics, mathematical statistics, that the the relevant issues are more fundamentally topological. That may sound shocking: what could rubber geometry have to do with learning or inductive inference? The answer is that the set of empirically verifiable propositions over a set of possibilities automatically satisfies the axioms of a topological space over possible worlds. Once that is recognized, there is a systematic translation between topology and familiar concepts and issues in learning, statistics and the the philosophy of science. This seminar will introduce the relevant topological concepts and will explore the methodological correspondences in detail. Topics covered include Hume's problem of induction, the problem of non-refutable theories and paradigm choice, convergence to the truth, simplicity and Ockham's razor, statistical model selection, causal discovery, and computability. The class will place students at the cutting edge of research in this fresh and exciting new area, and will provide them with a high-level, explanatory perspective that unifies much of the detail encountered in standard statistics and machine learning curricula.

80-551 Seminar on History of Philosophy: Smith and Hume

Fall: 9 units
David Hume and Adam Smith are the two most famous and influential figures of a philosophical era called the Scottish enlightenment. They had significant influences on one another and on the development of philosophy and the social sciences. In this class we will read work by both of them on topics related to ethics and the social sciences, and trace some of those ideas to modern philosophical and scientific ideas.

80-595 Senior Thesis

Fall and Spring
Philosophy Department majors writing a senior thesis, and are not participating in the Dietrich College Senior Honors Program, are given the opportunity to engage in original research under the direction of an individual faculty member. Research topics are selected by student.

Department of Psychology

Michael Tarr, Department Head

Erik Thiessen, Director of Undergraduate Education in Psychology

Chante Cox-Boyd, Associate Director of Undergraduate Education in Psychology

Emilie O'Leary, Academic Advisor in Psychology

Crista Crittenden, Academic Advisor in Psychology
www.cmu.edu/dietrich/psychology (http://www.cmu.edu/dietrich/psychology/)

Can newborn infants perceive the world as we do, or is it just "a blooming buzzing confusion"? Do personality, beliefs and social factors influence health? How do scientists and young children make discoveries, and what abilities make these insights possible? How does brain activity reveal differences in thinking? Can computers think the way people do?

These are some of the questions that psychologists at Carnegie Mellon are trying to answer.

For the student who is majoring in Psychology, Cognitive Science or Neuroscience, studying with faculty who are on the leading edge of research on questions like the above can be a very exciting experience.

The Psychology Department at Carnegie Mellon has long been noted as one of the pioneering Psychology Departments in the world, particularly in such areas as cognitive psychology, cognitive science, social psychology, developmental psychology, cognitive neuroscience, and health psychology. The Psychology Department offers 5 majors: B.A. and B.S. degrees in Psychology, as well as a B.S. degree in Cognitive Science and together with the Department of Biological Sciences, a unified B.S. double major in Psychology and Biological Sciences, and an Intercollege major in Neuroscience.

Statement of Community Standards

The Department of Psychology at Carnegie Mellon University strives to be a community that is academically and intellectually rigorous, as well as being diverse, inclusive, and respectful to all of its members. We aspire to promote a collegial professional environment in which all individuals can thrive and do their best work with community support and free from harassment, intimidation, or disrespect. We embrace and champion the following values:

Courtesy and Respect for Individuals

Excellence in the workplace requires an environment that promotes courtesy and civility towards every community member. Courtesy and civility require having mutual respect for one another. Therefore we expect all members of our community to take individual responsibility for:

- Viewing threats, hate speech, and harassment as totally unacceptable in an environment of free exchange of ideas amongst individuals.
- Encouraging all individuals to be respectful of others' views and opinions when expressing their own.
- Communicating with each other in ways that are clear, relevant, timely, constructive, and respectful.
- Making efforts to welcome and get to know all members of our community.
- Taking care of our common spaces rather than assuming that others will do it for us.

Diversity and Inclusion in Our Community

Academic excellence is built on a thriving and diverse community – something that is not possible without respectful treatment of all community members and intentional elimination of barriers to inclusion across groups. Therefore we expect all members of our community to take individual responsibility for:

- Providing mentoring and support for our colleagues.
- Prioritizing recruitment of people from diverse backgrounds into our community.
- Making efforts to be aware of the barriers faced by individuals and, whenever possible, making accommodations to remove or mitigate these barriers.
- Recognizing that with greater power within the academic hierarchy comes greater accountability for our actions and interactions.
- Making efforts to include our colleagues in intellectual and social gatherings during the workday whenever possible and appropriate.

The Major in Psychology

Psychology is a discipline that embraces both biological and social sciences. It is a science concerned with establishing principles and laws regarding the ways in which people think and behave through the scientific study of human behavior.

The orientation of the Carnegie Mellon Psychology curriculum is toward developing highly skilled and knowledgeable graduates. About half of our graduates go on to graduate or professional school. The remainder seek to expand their problem-oriented analytic skills to qualify themselves for job opportunities beyond those typically open to liberal arts students. Using the outcomes tool (https://www.cmu.edu/career/outcomes/post-grad-dashboard.html)created by CMU's Career & Professional Development Center, students have the opportunity to explore where some of our recent graduates have accepted employment and their positions.

Majors in the department are expected not only to learn about findings already established by psychologists, but also to become proficient in the investigation and analysis of behavior. This includes observing behavior, formulating hypotheses, designing experiments to test these hypotheses, running experiments, performing statistical analysis, and writing reports. The department has many resources for students to use in acquiring these skills. For instance, students interested in child development may be involved in the child development laboratory and observational facilities which are a part of the Carnegie Mellon Children's School (https://www.cmu.edu/dietrich/psychology/cs/) which operates under the department's aegis. Students interested in health or clinical psychology might have opportunities to do internships in applied settings, and all Psychology majors have access to extensive computer facilities for data analysis and simulation work. The department also has a state of the art set of undergraduate research laboratories and computer clusters, and through the Scientific Imaging & Brain Research Center, a magnet is in use for conducting brain imaging studies using fMRI.

In addition to formal class work, students are encouraged to participate in research projects where they may register and receive credit for freshmen research experience course 85-198 Research Training: Psychology, 85-506 Readings in Psychology, Fall research experience in 85-507 Research in Psychology or Spring research experience in 85-508 Research in Psychology. In the research in psychology course, the student may work on an ongoing research projects or develop and carry out a new research project with a faculty member. To compliment students research experience, the department requires 85-509 Research in Psychology Practicum, a 1 unit, pass/fail course which provides students with an opportunity to frame their research experience in a broader professional and scholastic perspective. More information on research labs that are recruiting can be found here (https://www.cmu.edu/dietrich/psychology/undergraduate/current-students/research-and-internships/research-opportunities/).

There is university and departmental funding (https://www.cmu.edu/dietrich/psychology/undergraduate/current-students/research-and-internships/undergrad-research-grants.html) available to help support student-initiated research projects and student travel to present research results at scientific meetings and conferences. In the Readings courses, the student reads extensively on a particular topic. The faculty member and student meet to discuss the readings, and the student writes a paper on the topic selected. The Psychology Department Website (http://www.cmu.edu/dietrich/psychology/), provides descriptions of faculty research interests (http://www.cmu.edu/dietrich/psychology/research-areas/) that the student can use in determining who should be approached to supervise a particular research or reading project.

Students interested in gaining field work experience via a number of internship opportunities available to them can receive credit through 85-482 Internship in Psychology, 85-480 Internship in Clinical Psychology or 85-484 Practicum in Child Development. Clinical internships are available with a variety of clinical settings including the prestigious Western Psychiatric Institute (https://www.upmc.com/locations/hospitals/western-psychiatric/?gclsrc=aw.ds&&utm_kxconfid=sws256pg0&utm_source=GOOGLE&utm_medium=cpc&utm_cam

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and Clinic (the teaching hospital of the Department of Psychiatry at the University of Pittsburgh Medical School). During the internship, students get first-hand experience with different clinical populations. Developmental Practicum experience is available in the department-run CMU Children's School (http://www.cmu.edu/dietrich/psychology/centers-and-facilities/).

If you would like to learn more about the BA and BS in Psychology, please reach out to Crista Crittenden ccritten@andrew.cmu.edu for more information.

Bachelor of Arts in Psychology

Mathematics 10-20 units

21-111-21-112	Calculus I-II	20

or

21-120	Differential and Integral Calculus *	10

*Students who place out of 21-120 with AP credit will have successfully completed the calculus requirement

Statistics Sequence 9 units

36-309	Experimental Design for Behavioral & Social Sciences	9
or 85-309	Statistical Concepts and Methods for Behavioral and Social Science	

Psychology Surveys 27 units

85-102	Introduction to Psychology *	9

Survey Courses - Complete Two		Units
85-104	Psychopathology	9
85-211	Cognitive Psychology	9
or 85-213	Human Information Processing and Artificial Intelligence	
85-219	Foundations of Brain and Behavior	9
85-221	Principles of Child Development	9
85-241	Social Psychology	9
85-251	Personality	9

* Introduction to Psychology cannot be substituted; AP credit does not count towards this requirement

Research Methods 18 units

Complete two courses.		
85-300	Introduction to Research Methods	9
85-310	Research Methods in Cognitive Psychology	9
85-311	Research Methods: Meta-Analysis	9
85-314	Cognitive Neuroscience Research Methods	9
85-320	Research Methods in Developmental Psychology	9
85-330	Analytic Research Methods	9
85-340	Research Methods in Social Psychology	9

Advanced Courses 18 units

Advanced psychology courses exist within four areas (cognitive, cognitive neuroscience, developmental, social and health psychology.) Any advanced content course or seminar in psychology or any psychology course higher than 85-349. Exceptions for the advanced course requirement are: 85-480, 85-482, 85-484, 85-506, 85-507, 85-508, 85-601, 85-602, 66-501, 66-502.

Psychology Breadth, Depth, and Application Electives 27 Units

Three courses from at least two of the Breadth, Depth and Application Categories. Please Consult the psychology department undergraduate website for approved Breadth Electives.

Depth

Any Psychology course between 85-300-85-499.
Exceptions for the course requirement are: 85-480, 85-482, 85-484, 85-506, 85-507, 85-508, 85-601, 85-602, 66-501, 66-50

Application

85-198	Research Training: Psychology	9
85-294	Teaching Assistantship	Var.
85-480	Internship in Clinical Psychology	Var.
85-482	Internship in Psychology	Var.
85-484	Practicum in Child Development	Var.
85-507	Research in Psychology	Var.
85-508	Research in Psychology	Var.
85-601	Senior Thesis	9
85-602	Senior Thesis	9
66-501	Dietrich College Senior Honors Thesis I	9
66-502	Dietrich College Senior Honors Thesis II Must receive a B or higher; 9 units min	9
99-270	Summer Undergraduate Research Apprenticeship	9

Breadth

Any 200 level Psychology survey course.		
85-104	Psychopathology	9
85-105	Hack Your Life	9
85-106	Animal Minds	9
85-107	The Psychology of Video Games	9

or

Choose from a list of courses found outside of the department with departments including Biological Sciences, History, English, HCI, Philosophy, Social Decision Sciences and Statistics. The elective list may change and for the most up to date list please contact either Crista Crittenden ccritten@andrew.cmu.edu or Emilie O'Leary at emilier@andrew.cmu.edu .

Computer Science Requirement

15-110	Principles of Computing	10
or 88-300	Programming and Data Analysis for Social Scientists	
or 15-112	Fundamentals of Programming and Computer Science	

Natural Science Requirement (B.A. 18 units of which include 9 units of Gen Ed Science)

The B.A. in psychology requires one course beyond the General Education requirement in natural science.

These courses can be selected from the following areas:

- 03-XXX Biology*
- 09-XXX Chemistry
- 33-XXX Physics

* Given the growing relevance of biology to psychology, it is strongly recommended to take a course in Biological Sciences

Bachelor of Science in Psychology

Mathematics 10-20 units

21-111-21-112	Calculus I-II	20

or

21-120	Differential and Integral Calculus *	10

***Students who place out of 21-120 with AP credit will have successfully completed the calculus requirement**

Statistics Sequence 9 units

36-309	Experimental Design for Behavioral & Social Sciences	9
or 85-309	Statistical Concepts and Methods for Behavioral and Social Science	

Psychology Surveys 27 units

85-102	Introduction to Psychology *	9

Survey Courses - Complete Two		Units
85-104	Psychopathology	9
85-211	Cognitive Psychology	9
or 85-213	Human Information Processing and Artificial Intelligence	
85-219	Foundations of Brain and Behavior	9
85-221	Principles of Child Development	9

85-241	Social Psychology	9
85-251	Personality	9

* Introduction to Psychology cannot be substituted; AP credit does not count towards this requirement

Research Methods 18 units

Complete two courses.		
85-300	Introduction to Research Methods	9
85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9
85-320	Research Methods in Developmental Psychology	9
85-330	Analytic Research Methods	9
85-340	Research Methods in Social Psychology	9

Advanced Courses 27 units

Advanced psychology courses exist within four areas (cognitive, cognitive neuroscience, developmental, social and health psychology.) Any advanced content course or seminar in psychology or any psychology course higher than 85-349. Exceptions for the advanced course requirement are:85-480,85-482,85-484,85-506,85-507,85-508,85-601,85-602,66-501,66-502.

Psychology Breadth, Depth, and Application Electives 27 Units

Three courses from at least two of the Breadth, Depth and Application Categories. Please Consult the psychology department undergraduate website for approved Breadth Electives.

Depth

Any Psychology course between 85-300–85-499. Exceptions for the course requirement are: 85-480, 85-482, 85-484, 85-506, 85-507, 85-508, 85-601, 85-602, 66-501, 66-502.

Application

85-198	Research Training: Psychology	9
85-294	Teaching Assistantship	Var.
85-480	Internship in Clinical Psychology	Var.
85-482	Internship in Psychology	Var.
85-484	Practicum in Child Development	Var.
85-507	Research in Psychology	Var.
85-508	Research in Psychology	Var.
85-601	Senior Thesis	9
85-602	Senior Thesis	9
66-501	Dietrich College Senior Honors Thesis I	9
66-502	Dietrich College Senior Honors Thesis II Must receive a B or higher; 9 units min	9

Breadth

Any 200 level Psychology survey course.		
85-104	Psychopathology	9
85-106	Animal Minds	9
85-107	The Psychology of Video Games	9

or

Choose from a list of courses found outside of the department with departments including Biological Sciences, History, English, HCI, Philosophy, Social Decision Sciences and Statistics. The elective list may change and for the most up to date list please contact either Crista Crittenden ccritten@andrew.cmu.edu or Emilie O'Leary at emilier@andrew.cmu.edu

Computer Science Requirement 10 units

15-110	Principles of Computing	10
or 88-300	Programming and Data Analysis for Social Scientists	
or 15-112	Fundamentals of Programming and Computer Science	

NATURAL SCIENCE REQUIREMENT (B.S. 27 UNITS OF WHICH INCLUDE 9 UNITS OF GEN ED SCIENCE)

The B.S. in psychology requires two courses beyond the General Education requirement in natural science.

- 03-xxx Biology*
- 09-xxx Chemistry
- 33-xxx Physics

* Given the growing relevance of biology to psychology, it is strongly recommended to take at least one course in Biological Sciences

Additional Major in Psychology

In order to complete an additional major in Psychology, a student must fulfill all of the Psychology major requirements within the department -- in other words, the breadth requirement, computing requirement, three survey courses, two research methods courses, and two advanced courses. These courses must include at least 81 units, plus calculus prerequisites and the 36-200 statistics course or equivalent and 36-309/85-309 . In addition, psychology additional major candidates must complete one science course beyond the GenEd requirement if required for college.

Concentrations within the Psychology Major

Students who wish to focus their Psychology program on a specific area can do so either by the careful selection of Psychology elective courses focusing on their area of interest or by pursuing one of the following concentrations. Concentrations are not a required part of the major.

Please reach out to Crista Crittenden ccrittenden@andrew.cmu.edu to declare the concentration. The declared concentration will appear in Stellic. The completion of a concentration will be recognized in the Psychology Graduation Program.

Health-Psychology Concentration

For Psychology majors who wish to have a focus of their study on Health Psychology, the following courses should be selected as part of their Psychology Major in conjunction with their Psychology advisor's approval.

As part of the natural science requirement, choose two of the following		Units
03-121	Modern Biology	9
03-132	Basic Science to Modern Medicine	9
03-133	Neurobiology of Disease	9
03-135	Structure and Function of the Human Body	9
As part of the psychology breadth requirement:		
85-219	Foundations of Brain and Behavior	9
85-241	Social Psychology	9
As part of the psychology Research Methods requirements:		
85-340	Research Methods in Social Psychology	9
As part of the advanced coursework in psychology requirement, at least two of the following:		
85-358	Pro-Social Behavior	9
85-422	Clinical Psychology: Science and Practice	9
85-442	Health Psychology	9
85-443	Social Factors and Well-Being	9
85-446	Psychology of Gender	9
As part of the Breadth, Depth and Application requirement, at least one of the following		
85-480	Internship in Clinical Psychology	9
85-507	Research in Psychology	9
85-508	Research in Psychology	9
85-482	Internship in Psychology	9
or an additional advanced psychology seminar from the list above		

Cognitive-Neuroscience Concentration

For Psychology majors who wish to have a focus of their study be on Cognitive Neuroscience, the following courses should be selected as part of their Psychology Major in conjunction with their Psychology advisor's approval.

As part of the natural science requirement, choose two of the following		Units
03-121	Modern Biology	9
03-363	Systems Neuroscience	9
03-366	Neuropharmacology: Drugs, Brain and Behavior	9

As part of the psychology Breadth requirement:		
85-211	Cognitive Psychology	9
85-219	Foundations of Brain and Behavior	9

As part of the Research Methods requirement:		
85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9

As part of the advanced coursework in psychology requirement, at least two of the following:		
85-351	What is Attention?	9
85-356	Expertise: The cognitive (neuro)science of mastering almost any skill	9
85-359	Introduction to Music Cognition Research	9
85-370	Perception	9
85-382	The Psychology and Neuroscience of Consciousness	9
85-385	Auditory Perception: Sense of Sound	9
85-407	How the Brain Makes Meaning	9
85-408	Visual Cognition	9
85-414	Cognitive Neuropsychology	9
85-419	Introduction to Parallel Distributed Processing	9
85-432	Data Science for Psychology and Neuroscience	9
85-435	Biologically Intelligent Exploration	9

As part of the Breadth, Depth and Application requirement, at least one of the following		
85-507	Research in Psychology	Var.
85-508	Research in Psychology	Var.
88-342	The Neuroscience of Decision Making	9
Or an additional advanced psychology seminar from the list above		

Learning and Developmental Psychology Concentration

For Psychology majors who wish to have a focus of their study be on Behavior and Developmental Psychology, the following courses should be selected as part of their Psychology Major in conjunction with their Psychology advisor's approval.

As part of the B.S. science requirement, choose one of the following		Units
03-125	Evolution	9
03-121	Modern Biology	9
03-365	Neural Correlates of Learning and Memory	9

As part of the psychology Breadth requirement:		
85-211	Cognitive Psychology	9
85-221	Principles of Child Development	9

As part of the psychology Research Methods Requirement:		
85-310	Research Methods in Cognitive Psychology	9
85-320	Research Methods in Developmental Psychology	9

As part of the advanced coursework in psychology requirement, at least two of the following:		
85-343	Children, Race, and Racism	9
85-351	What is Attention?	9
85-354	Infant Language Development	9
85-360	Origins of Intelligence	9
85-363	Attention, Its Development and Disorders	9
85-375	Crosscultural Psychology	9
85-394	Development in Context: Applying Theory and Research to Support Thriving	9
85-407	How the Brain Makes Meaning	9
85-408	Visual Cognition	9
85-418	Infant development: Inside the Mind of Babies	9

As part of the Breadth, Depth and Application requirement, at least two of the following		
85-294	Teaching Assistantship	Var.
85-484	Practicum in Child Development	Var.
85-507	Research in Psychology	Var.
85-508	Research in Psychology	Var.
05-291	Learning Media Design	12
05-418	Design Educational Games	12
57-331	Principles of Education	9
Or an additional advanced psychology seminar from the list above		

Cognitive Psychology Concentration

For Psychology majors who wish to have a focus of their study be on Cognitive Psychology and/or Cognitive Modeling, the following courses should be selected as part of their Psychology Major in conjunction with their Psychology advisor's approval.

As part of the B.S. science requirement:		Units
03-121	Modern Biology	9

As part of the psychology Breadth requirement:		
85-211	Cognitive Psychology	9

As part of the psychology Research Methods requirement:		
85-310	Research Methods in Cognitive Psychology	9

As part of the advanced coursework in psychology requirement, at least two of the following:		
85-351	What is Attention?	9
85-356	Expertise: The cognitive (neuro)science of mastering almost any skill	9
85-359	Introduction to Music Cognition Research	9
85-360	Origins of Intelligence	9
85-363	Attention, Its Development and Disorders	9
85-370	Perception	9
85-385	Auditory Perception: Sense of Sound	9
85-395	Applications of Cognitive Science	9
85-407	How the Brain Makes Meaning	9
85-408	Visual Cognition	9
85-412	Cognitive Modeling	9
85-414	Cognitive Neuropsychology	9
85-419	Introduction to Parallel Distributed Processing	9
85-421	Language and Thought	9
85-435	Biologically Intelligent Exploration	9

As part of the Breadth, Depth and Application requirement, at least one of the following		
85-507	Research in Psychology	Var.
85-508	Research in Psychology	Var.
05-391	Designing Human Centered Software	12
05-413	Human Factors	9
80-305	Game Theory	9
80-484	Language and Thought	9
Or an additional advanced psychology seminar		

Social-Personality Psychology Concentration

For Psychology majors who wish to have a focus of their study be on Social and/or Personality Psychology, the following courses should be selected as part of their Psychology Major in conjunction with their Psychology advisor's approval.

As part of the Psychology Breadth requirement:		Units
85-104	Psychopathology	9
85-241	Social Psychology	9
85-251	Personality	9

As part of the Psychology Research Methods requirement:		
85-340	Research Methods in Social Psychology	9

As part of the advanced coursework in psychology requirement, at least two of the following:		
85-350	Psychology of Prejudice	9
85-358	Pro-Social Behavior	9
85-375	Crosscultural Psychology	9
85-377	Attitudes and Persuasion	9
85-442	Health Psychology	9
85-443	Social Factors and Well-Being	9

85-444	Relationships	9
85-446	Psychology of Gender	9

As part of the Breadth, Depth and Application requirement, at least one of the following		
85-507	Research in Psychology	Var.
85-508	Research in Psychology	Var.
85-482	Internship in Psychology	Var.
05-320	Social Web	12
Or an additional advanced psychology seminar from the list above		

Clinical/Counseling Psychology Concentration

For Psychology majors who wish to have a focus of their study be on Clinical/Counseling Psychology, the following courses should be selected as part of their Psychology Major in conjunction with their Psychology advisor's approval.

One of the following:		
03-133	Neurobiology of Disease	9
03-366	Neuropharmacology: Drugs, Brain and Behavior	9
09-303	Hooked: The Molecular Basis of Addiction	6

As part of the Psychology Breadth requirement at least two of the following:		Units
85-221	Principles of Child Development	9
85-241	Social Psychology	9
85-251	Personality	9

Required coursework:		
85-104	Psychopathology	9
85-422	Clinical Psychology: Science and Practice	9
85-480	Internship in Clinical Psychology	9

As part of the Psychology Research Methods requirements at least one of the following:		
85-320	Research Methods in Developmental Psychology	9
85-340	Research Methods in Social Psychology	9

As part of the advanced coursework in psychology requirement, at least two of the following:		
85-343	Children, Race, and Racism	9
85-358	Pro-Social Behavior	9
85-363	Attention, Its Development and Disorders	9
85-375	Crosscultural Psychology	9
85-377	Attitudes and Persuasion	9
85-442	Health Psychology	9
85-443	Social Factors and Well-Being	9
85-444	Relationships	9
85-446	Psychology of Gender	9

Neuroscience Major

The Psychology Department at Carnegie Mellon University has a major focus on the role of the brain and nervous system in cognition and behavior, including biological approaches involving the health impact that arises from the interaction of behavior with the nervous, endocrine, and immune systems. These interests are manifested in faculty research (http://www.cmu.edu/dietrich/psychology/research-areas/), departmental and university centers that operate from or heavily involve the department (e.g., the Center for Cognitive Brain Imaging (http://www.ccbi.cmu.edu/), and the Center for the Neural Basis of Cognition (http://www.cnbc.cmu.edu/)) as well as undergraduate coursework (http://www.cmu.edu/dietrich/psychology/undergraduate/) and graduate coursework.

For undergraduates, there are a number of ways in which students with an interest in these approaches can pursue that interest in an organized fashion. Major requirements for the Bachelor of Science in Neuroscience can be found under Intercollege Programs (p. 891).

Carnegie Mellon University recently launched *BrainHub* – an initiative designed to leverage its core strengths in cognitive science, engineering, and computer science, and our emerging excellence in biological sciences, to harness the technology that helps the world explore brain and behavior. Students will be able to take advantage of exciting opportunities such as lectures hosted on various topics, newly funded CMU campus research projects trying to answer pressing questions in brain science and the many global partnerships with other institutions all with the same motivating goal to enhance and increase research in brain sciences.

Finally, for any interested student, there is a Minor in Cognitive Neuroscience (p. 478) available through the Psychology department.

The Major in Cognitive Science

The Psychology Department offers a B.S. degree in Cognitive Science. The field of cognitive science has grown out of increasingly active interaction among psychology, linguistics, artificial intelligence, philosophy, and neuroscience. All of these fields share the goal of understanding intelligence. By combining these diverse perspectives, students of cognitive science are able to understand cognition at a deep level. Because this major is administered by the Psychology Department, it focuses on human cognition and the experimental study of the human mind as illuminated by the techniques of the above disciplines.

Cognitive Science Curriculum

The Cognitive Science major is only offered as a B.S. degree. Candidates should complete before the junior year the calculus requirement 21-120

(or alternatively 21-111/21-112) and a statistics sequence (36-200 or equivalent and if possible, 36-309/85-309). In addition, candidates complete 15-112 Fundamentals of Programming and Computer Science, as their departmental computing course.

Because of the number and sequential nature of required courses, prospective Cognitive Science majors are encouraged to begin course work for the major prior to junior year. In particular, completion of calculus, 36-200, and 85-211 or 85-213 before the junior year will enable students to complete one of the following 85-310/85-314/85-330and 36-309/85-309 and by the Fall semester of their sophomore or junior year and, if interested, to then take advantage of research opportunities in the department. The Psychology Department (https://www.cmu.edu/dietrich/psychology/undergraduate/current-students/research-and-internships/research-opportunities/) website has more information regarding research for credit opportunities available to undergraduates.

Computing Prerequisite 10 units

15-112	Fundamentals of Programming and Computer Science	12

Mathematics 29-30 units

21-111-21-112	Calculus I-II	20
or		
21-120	Differential and Integral Calculus *	10
21-127	Concepts of Mathematics	12

*Students who place out of 21-120 will have fulfilled the calculus requirement

.

Statistics Sequence 18 units

36-200	Reasoning with Data	9
36-309	Experimental Design for Behavioral & Social Sciences	9
or 85-309	Statistical Concepts and Methods for Behavioral and Social Science	

Computational/Cognitive Modeling Core 29–31 units

Two of the following:		Units
15-122	Principles of Imperative Computation	12
15-150	Principles of Functional Programming	12
15-251	Great Ideas in Theoretical Computer Science	12

Plus one of the following:		Units
85-412	Cognitive Modeling	9
85-419	Introduction to Parallel Distributed Processing	9
85-435	Biologically Intelligent Exploration	9

Cognitive Psychology Core 27 units

		Units
85-211	Cognitive Psychology	9
or 85-213	Human Information Processing and Artificial Intelligence	

Plus two of the following, one of which need to be 85-xxx:		Units
85-219	Foundations of Brain and Behavior	9
or 85-106	Animal Minds	
or 80-180	Nature of Language: An Introduction to Linguistics	
85-351	What is Attention?	9
85-359	Introduction to Music Cognition Research	9
85-370	Perception	9
85-375	Crosscultural Psychology	9
85-382	The Psychology and Neuroscience of Consciousness	9
85-385	Auditory Perception: Sense of Sound	9
85-395	Applications of Cognitive Science	9
85-407	How the Brain Makes Meaning	9
85-408	Visual Cognition	9
85-414	Cognitive Neuropsychology	9
85-421	Language and Thought	9
80-381	Meaning in Language	9
80-310	Formal Logic	9
80-315	Logics for Knowledge and Belief	9
80-383	Language in Use	9
05-413	Human Factors	9
11-344	Machine Learning in Practice	12

Cognitive Science Concentration

(3 courses, concentration approval required)

These three courses are chosen in conjunction with your advisor to form a coherent area of concentration from the course list under "Cognitive Science Concentration" in the current Undergraduate Catalog. Before proceeding with the choice of courses, students must fill out the concentration form, obtained from Emilie O'Leary in Baker Hall 339, with a description of the concentration area and the planned set of three courses. Courses not represented on the list may, with pre-approval of advisor and department, be used to satisfy part of this requirement. **The three courses are not required to be within any single category below but be coherent within the major and the focus may vary across disciplinary boundaries.** Courses taken for the major requirements can not be double counted in the concentration.

Computer Science

16-385	Computer Vision	12
15-453	Formal Languages, Automata, and Computability	9
15-213	Introduction to Computer Systems	12

Psychology

85-219	Foundations of Brain and Behavior	9
85-354	Infant Language Development	9
85-360	Origins of Intelligence	9
85-363	Attention, Its Development and Disorders	9
85-370	Perception	9
85-375	Crosscultural Psychology	9
85-385	Auditory Perception: Sense of Sound	9
85-395	Applications of Cognitive Science	9
85-351	What is Attention?	9
85-359	Introduction to Music Cognition Research	9
85-382	The Psychology and Neuroscience of Consciousness	9
85-408	Visual Cognition	9
85-412	Cognitive Modeling	9
85-414	Cognitive Neuropsychology	9
85-419	Introduction to Parallel Distributed Processing	9
85-421	Language and Thought	9
85-432	Data Science for Psychology and Neuroscience	9

Philosophy

80-210	Logic and Proofs	9
80-211	Logic and Mathematical Inquiry	9
80-220	Philosophy of Science	9
80-249	AI, Society, and Humanity	9
80-254	Analytic Philosophy	9
80-255	Pragmatism: Making Ideas Work	9
80-270	Problems of Mind and Body: Meaning and Doing	9
80-271	Mind and Body: The Objective and the Subjective	9
80-310	Formal Logic	9
80-311	Undecidability and Incompleteness	9

Human Computer Interaction

05-317	Design of Artificial Intelligence Products	12
05-320	Social Web	12
05-333	Gadgets, Sensors and Activity Recognition in HCI	12
05-430	Programming Usable Interfaces	15
05-418	Design Educational Games	12
05-413	Human Factors	9
05-410	User-Centered Research and Evaluation	12
05-738	Evidence-Based Educational Design	12

Linguistics

80-180	Nature of Language: An Introduction to Linguistics	9
80-280	Linguistic Analysis	9
80-315	Logics for Knowledge and Belief	9
76-385	Introduction to Discourse Analysis	9

Machine Learning

10-301	Introduction to Machine Learning	12
10-335	Art and Machine Learning	12
11-344	Machine Learning in Practice	12
11-411	Natural Language Processing	12

Decision Sciences

88-275	Bubbles: Data Science for Human Minds	9
88-302	Behavioral Decision Making	9
88-231	Thinking in Person vs. Thinking Online	9
88-230	Human Intelligence and Human Stupidity	9
88-223	Decision Analysis	12
88-120	Reason, Passion and Cognition	9

Neurosciences

03-133	Neurobiology of Disease	9
03-365	Neural Correlates of Learning and Memory	9
03-366	Neuropharmacology: Drugs, Brain and Behavior	9
86-375	Computational Perception	9
03-362	Cellular Neuroscience	9
03-363	Systems Neuroscience	9
42-202	Physiology	9
15-386	Neural Computation	9
15-883	Computational Models of Neural Systems	12
03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	9
03-360	Genomics and Epigenetics of the Brain	9

Science Requirement

The Cognitive Science program requires two additional science courses beyond Dietrich College's General Education requirements or additional majors or minors declared.

These can be selected from any one of the following areas.	
03-xxx	Biology *
09-xxx	Chemistry
33-xxx	Physics

* Those interested in a cognitive neuroscience focus are recommended to take biology courses, including if possible, 03-362, or 03-363.

Additional Major in Cognitive Science

In order to complete a double major in Cognitive Science, a student must fulfill the major requirements as listed under the Cognitive Science major. These include the programming requirement (15-112), the Mathematics and Statistics prerequisites, Computational/Cognitive Modeling Core, The Cognitive Psychology Core, the Cognitive Science Concentration Requirement, and the Supplementary Science Requirement. Students will be assigned a department advisor to help plan their program of studies in Cognitive Science.

Unified Double Major in Psychology & Biological Sciences

Veronica Hinman, *Department Head, Biological Sciences*

Susanne Ferber, *Department Head, Psychology*

This major is intended to reflect the interdisciplinary nature of current research in the fields of biology and psychology, as well as the national trend in some professions to seek individuals broadly trained in both the social and natural sciences.

Note: Students entering from the Dietrich College of Humanities and Social Sciences will earn a Bachelor of Science in Psychology and Biological Sciences. Students in the Mellon College of Science will earn a Bachelor of Science in Biological Sciences and Psychology.

Depending on a student's home college (DC or MCS), General Education (GenEd) requirements will be different. GenEd requirements for DC (p. 353) and MCS (p. 560) are found on their respective Catalog pages.

Degree Requirements:

Biological Sciences		Units
03-151	Honors Modern Biology	10
or 03-121	Modern Biology	
03-201	Undergraduate Colloquium for Sophomores *Only required for MCS Students	2
03-220	Genetics	9
or 03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	
03-231	Honors Biochemistry	9
03-320	Cell Biology	9
03-343	Experimental Techniques in Molecular Biology	12
03-411	Topics in Research	1
03-412	Topics in Research	1
03-xxx	General Biology Elective [1]	9
03-3xx	Advanced Biology Elective [1]	18
Total Biology units		**80**

[1] Please see description and requirements for electives under the B.S. in Biological Sciences section of this Catalog.

Mathematics, Statistics, Physics and Computer Science		Units
21-120	Differential and Integral Calculus	10
21-124	Calculus II for Biologists and Chemists	10
or 21-122	Integration and Approximation	
36-200	Reasoning with Data	9
36-309	Experimental Design for Behavioral & Social Sciences	9
or 85-309	Statistical Concepts and Methods for Behavioral and Social Science	
33-121	Physics I for Science Students [3]	12
or 33-141	Physics I for Engineering Students	
15-110	Principles of Computing	10-12
or 15-112	Fundamentals of Programming and Computer Science	
99-101	Core@CMU	3
Total Science units		**63-65**

[3] MCS students must also complete 33-122 Physics II for Biological Sciences & Chemistry Students.

Chemistry		Units
09-105	Introduction to Modern Chemistry I	10
09-106	Modern Chemistry II	10
09-217	Organic Chemistry I	9
09-218	Organic Chemistry II	9
09-207	Techniques in Quantitative Analysis	9
09-208	Techniques for Organic Synthesis and Analysis	9
Total Chemistry units		**56**

Psychology Courses		Units
85-102	Introduction to Psychology	9
85-219	Foundations of Brain and Behavior	9
85-xxx	Survey Psychology Courses *	18
85-310	Research Methods in Cognitive Psychology	9
or 85-300	Introduction to Research Methods	
or 85-314	Cognitive Neuroscience Research Methods	
or 85-320	Research Methods in Developmental Psychology	
or 85-330	Analytic Research Methods	
or 85-340	Research Methods in Social Psychology	
85-3xx	Advanced Psychology Electives	18
Total Psychology units		**63**

* Excluding 85-104 Psychopathology

Additional Advanced Elective 9 units

(Choose one of the following courses)		
85-3xx	Advanced Psychology Elective	9
or		
03-3xx	Advanced Biology Elective	9

Additional Laboratory or Research Methods 9-12 units

(Choose one of the following courses)		
03-344	Experimental Biochemistry	12
03-345	Experimental Cell and Developmental Biology	12
03-346	Experimental Neuroscience	12
85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9
85-320	Research Methods in Developmental Psychology	9
85-330	Analytic Research Methods	9
85-340	Research Methods in Social Psychology	9

Elective Units	Units
Free Electives	33-36
MCS Nontechnical Breadth or DC General Education requirements	36-48
Total Elective units	**69-84**

Minimum number of units required for degree: 360

Minors in Psychology and Cognitive Neuroscience

Minor in Psychology 72 units

I. Introductory course		
85-102	Introduction to Psychology *	9

*A survey course can be taken in place of 85-102.

II. Area Survey courses		
Complete one course		
85-104	Psychopathology	9
85-211	Cognitive Psychology	9
or 85-213	Human Information Processing and Artificial Intelligence	
85-219	Foundations of Brain and Behavior	9
85-221	Principles of Child Development	9
85-241	Social Psychology	9
85-251	Personality	9

III. Statistics		
36-200	Reasoning with Data	9

36-309	Experimental Design for Behavioral & Social Sciences	9
or 85-309	Statistical Concepts and Methods for Behavioral and Social Science	

27 unitsUpper Level Courses

Complete three courses from categories IV and V, with at least one course from each.

IV. Research Methods Courses * (minimum 9 units)		
85-300	Introduction to Research Methods	9
85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9
85-320	Research Methods in Developmental Psychology	9
85-330	Analytic Research Methods	9
85-340	Research Methods in Social Psychology	9

* Prerequisites for all Research Methods courses: 36-309/85-309 and the appropriate survey course, except 85-300 which has a pre req of 36-200 and a survey course.

V. Advanced courses (minimum 9 units)

Advanced psychology courses exist within four areas (cognitive, cognitive neuroscience, developmental, social and health psychology.) Any advanced content course or seminar in psychology or any psychology course higher than 85-350. Exceptions for the advanced course requirement are: 85-480, 85-482, 85-484, 85-484, 85-506, 85-507, 85-508, 85-601, 85-602, 66-501, 66-502.

Psychology Elective - Anything with 85-XXX number can be used 9 units

Minor in Cognitive Neuroscience 63 units

The minor in Cognitive Neuroscience offered by the Department of Psychology is similar to the Neuroscience Minor offered by the Department of Biological Sciences. The differences between the two forms of the minor are determined by one required course, and additionally, by the students' choice of distribution electives. The requirements for the Cognitive Neuroscience Minor include 7 courses: four required courses, and three distribution and elective courses.

Because of the curriculum within this minor may overlap with some degree requirements, no more than 2 courses fulfilling Neuroscience or Cognitive Neuroscience Minor requirements may count towards a student's major or other minor requirements.

Cognitive Neuroscience Curriculum

Required Coursework

03-121	Modern Biology	9
03-363	Systems Neuroscience	9
85-219	Foundations of Brain and Behavior	9
or 03-161	Molecules to Mind	
85-211	Cognitive Psychology	9

Distribution Requirements

Three courses, including at least 1 from each of the following categories

Approaches to Cognitive Neuroscience		
85-213	Human Information Processing and Artificial Intelligence	9
85-314	Cognitive Neuroscience Research Methods	9
85-382	The Psychology and Neuroscience of Consciousness	9
85-407	How the Brain Makes Meaning	9
85-408	Visual Cognition	9
85-412	Cognitive Modeling	9
85-414	Cognitive Neuropsychology	9
85-419	Introduction to Parallel Distributed Processing	9
85-435	Biologically Intelligent Exploration	9
15-386	Neural Computation	9
86-375	Computational Perception	9
85-432	Data Science for Psychology and Neuroscience	9

Cognitive Neuroscience Electives		
03-133	Neurobiology of Disease	9
03-362	Cellular Neuroscience	9
03-365	Neural Correlates of Learning and Memory	9
85-211	Cognitive Psychology	9
85-359	Introduction to Music Cognition Research	9
85-360	Origins of Intelligence	9
85-370	Perception	9
85-385	Auditory Perception: Sense of Sound	9
85-351	What is Attention?	9
85-106	Animal Minds	9
85-104	Psychopathology	9

The Honors Program

The Honors Program provides recognition of outstanding performance by students in the Psychology department. Participation enables students to pursue their own research ideas through completion of an honors thesis. The honors thesis is completed during the senior year. By completing a thesis, the student earns 18 units of credit and qualifies for graduation with “College Honors.” To qualify for the Honors Program, the student must maintain a quality point average of at least 3.50 in the major and 3.25 overall. More information on the Honor program can be found here (http://www.cmu.edu/dietrich/undergraduate/programs/shp/).

A year long departmental senior thesis course exists (66-501 and 66-502) for students interested in pursuing a sizable research project who do not qualify for the honors program. More information can be obtained by contacting Emilie O'Leary at emilier@andrew.cmu.edu.

Faculty

JOHN R. ANDERSON, Richard King Mellon University Professor of Psychology and Computer Science – Ph.D., Stanford University; Carnegie Mellon, 1978–

JESSICA CANTLON, Ronald J. and Mary Ann Zdrojkowski Associate Professor of Developmental Neuroscience – PhD, Duke University; Carnegie Mellon, 2007–

SHARON CARVER, Teaching Professor, Psychology; Associate Dean of Student Affairs, Dietrich College – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1993–

CHANTE COX-BOYD, Associate Teaching Professor – Ph.D., University of North Carolina at Chapel Hill; Carnegie Mellon, 1999–

DAVID CRESWELL, Professor – Ph.D., University of California, Los Angeles; Carnegie Mellon, 2008–

KASEY CRESWELL, Associate Professor – Ph.D., University of Pittsburgh; Carnegie Mellon, 2012–

BROOKE C. FEENEY, Professor – Ph.D., State University of New York at Buffalo; Carnegie Mellon, 2001–

SUSANNE FERBER, Department Head – Ph.D, University of Osnabruck; Carnegie Mellon, 2000–

ANNA FISHER, Associate Professor – Ph.D., The Ohio State University; Carnegie Mellon, 2006–

VICKI S. HELGESON, Professor – Ph.D., University of Denver; Carnegie Mellon, 1990–

LAURIE HELLER, Teaching Professor – Ph.D., University of Pennsylvania; Carnegie Mellon, 2009–

MARCEL A. JUST, D. O. Hebb University Professor of Psychology – Ph.D., Stanford University; Carnegie Mellon, 1972–

ROBERTA KLATZKY, Charles J. Queenan Jr., University Professor of Psychology – Ph.D., Stanford University; Carnegie Mellon, 1993–

KENNETH R. KOEDINGER, Hillman Professor & METALS Program Director – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2001–

PHOEBE LAM, Assistant Professor – PhD, Northwestern University; Carnegie Mellon, 2023–

MARSHA C. LOVETT, Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2000–

BRIAN MACWHINNEY, Teresa Heinz Professor of Cognitive Psych – Ph.D., University of California, Berkeley; Carnegie Mellon, 1981–

BRADFORD MAHON, Associate Professor – PhD, Harvard University ; Carnegie Mellon, 2009–

KODY MANKE, Assistant Teaching Professor – Ph.D, Standford University; Carnegie Mellon, 2016–

DAVID PLAUT, Professor of Psychology – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1994–

DAVID RAKISON, Associate Professor – D.Phil., University of Sussex; Carnegie Mellon, 2000–

MICHAEL TARR, Professor, Kavčić-Moura Professor of Cognitive and Brain Science – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2009–

ERIK D. THIESSEN, Associate Professor, Director of Undergraduate Education in Psychology – Ph.D., University of Wisconsin, Madison; Carnegie Mellon, 2004–

MICHAEL TRUJILLO, Assistant Professor – PhD, Virginia Commonwealth University; Carnegie Mellon, 2018–

JONATHAN TSAY, Assistant Professor – Ph.D., UC Berkeley; Carnegie Mellon, 2023–

TIMOTHY VERSTYNEN, Associate Professor and Co Director of the CMU-Pitt BRIDGE Center – Ph.D., University of California, Berkeley ; Carnegie Mellon, 2006–

Department of Psychology Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

85-102 Introduction to Psychology

Fall and Summer: 9 units
The world is a crazy, confusing place. Much of what we encounter is ambiguous, dynamic, and misleading. Somehow, we have to make sense of it. This class is about how we do that. The course provides an overview of the major areas of scientific psychology, exploring the models of our mind, brain, and behavior that explain wide areas of human (and non-human) functioning. Topics range from neuroscience and the biological basis of behavior, to memory and thought, to social interaction and psychological development over the lifespan, to abnormal psychology, psychopathology, and treatment. Tuesday and Thursday lectures provide a broad survey of topics and findings in psychology. In recitation sections students get hands on experiencing thinking about psychological science by designing and running psychological studies and discussing the real world implications of the concepts they have investigated. While all sections will be completing the same activities, some of the sections are themed. Themed sections will frame the discussion in the context of the theme, thus allowing students in those sections to better appreciate the links between the work being done in the class and the theme of that section. However, the core material will be the same and all sections will prepare students equally well for exams and upper division courses. General (unthemed) sections will sample across themes and topics, rather than being focused on a single theme.
At the end of this course, students will not only be more knowledgeable about psychology, but be able to apply their knowledge about psychology to be better thinkers, learners, and consumers of information in general.
Themed sections: Design - Register through Design Medicine, health, and Biosciences - Section I Decision Science, business, and economics - Section A

85-104 Psychopathology

Fall: 9 units
This course provides an introduction to the science and practice of psychopathology. Students will examine definitions of psychopathology in a historical and contemporary context, explore issues relevant to diagnosis and patient care, and be introduced to various diagnostic categories for psychological disorders. Students will also learn about potential determinants of and treatments for psychological disorders in the context of major theories and empirical findings in the field. Emphasis will be placed on three major paradigms in psychopathology: genetics, neuroscience, and cognitive behavioral. An assigned memoir, case studies, and short video clips will be used to illustrate the human side of mental illness.

85-105 Hack Your Life

Spring: 9 units
Hack your life! College offers a new opportunity to hack your life to explore who you are, how you learn, and how you can take better care of yourself. This course will give you the opportunity to fully explore the CMU student experience, the science of learning, and to explore issues central to students (e.g., resilience, social connections, mental health, sleep). Much of this course will focus on providing discussion, strategies, and practices around how you can live a better life, and nurture your happiness and health.

85-106 Animal Minds

Intermittent: 9 units
With intricate cultures, impressive technology, and layered social lives, humans seem to stand apart from their animal kin. However, humans and non-human animals share many aspects of their mental lives, and, upon closer inspection, some animals even reveal cognitive abilities far beyond the capacities of humans. Through comparing and contrasting human and non-human cognition, we can learn about human psychological uniqueness and its evolutionary origins, and fundamental properties of cognitive processes in general

85-107 The Psychology of Video Games

Intermittent: 9 units
This course will explore how the features of video game design and use relate to characteristics of human psychology. We will discuss design and use issues such as microtransactions, online gaming communities, and reward/scoring, and try to understand how these features are (or are not!) well suited to the human mind, with a particular focus on learning, memory, attention, and perception. Student presence will sometimes be required but many course sessions will be asynchronous.

85-120 Demystifying Freud and the Discipline of Psychology

Intermittent: 3 units
Regardless of discipline, an understanding of human thought and behavior is essential in navigating one's environment and work. Psychology, the science that can guide this understanding, is often misunderstood by the general public. Throughout the world, when psychology is mentioned, the name that often comes to mind is Sigmund Freud. Many of the misconceptions regarding psychology started with misinterpretations of Freud's work and concepts. Using Freud's most well-known concepts, this course will introduce students to what psychology is, and what it isn't - in hopes of illustrating what use psychological principles can be in a plethora of academic disciplines. In particular, students will learn how to apply these principles to modern day research settings with a specific focus on health and well-being research. Students will not only gain insight into their own academic and career paths, but into their own personality and health as well. Course work will consist of class attendance, weekly course readings and online discussions, one exam, and a final paper.

85-150 Cognitive Science at CMU and beyond

All Semesters: 9 units
This course provides an introduction to the broad field of Cognitive Science, with a particular emphasis on psychological methods and the role of memory in cognition. In addition to giving students a sense of some of the applied areas that use Cognitive Science research, this course gives a sampling of research questions and phenomena to help decide whether this might be a good choice for a major or minor while studying at Carnegie Mellon. Topics that will be discussed include attention, perception, cognitive illusions, memory, language acquisition and skill acquisition. There is an emphasis of the applications of cognitive science to real life situations, for example, best practices for learning in an academic setting. The course will also provide the opportunity to learn about the scientific method and collect data by running an experiment (online, on a computer). The class meets twice per week for 1.5 hours for each class. The plan is to focus more on lecture and discussion of readings on Tuesday and focus more on teaching new skills such as experimental design, data analysis and running experiments on Thursday.

85-198 Research Training: Psychology

Fall and Spring: 9 units
See course url and click on (forms and guides informational handout page) then click on current freshman-sophmore research training courses for listing of research training course descriptions.

Course Website: https://www.cmu.edu/dietrich/students/undergraduate/programs/research-training-program.html

85-211 Cognitive Psychology

Fall and Spring: 9 units
This course focuses on the fascinating way that the brain processes the world and allows us to interact with it. Aside from covering the major topics in cognitive psychology (language, memory, visual processing, attention and cognitive control), it includes an introduction to some of the most recent approaches to studying human cognition. The course is set up to highlight the connection between cognitive studies and skills in various majors such as computer science, math, statistics, and medicine. It is also structured to foster the necessary skills for the critical analysis of complex problems.

85-213 Human Information Processing and Artificial Intelligence

Fall: 9 units
This course will review the information-processing challenges that humans face. We will discuss how these challenges are dealt with in the domains of attention, perception, memory, problem solving, reasoning, decision-making, and language. We will compare and contrast how these challenges are dealt with by humans and artificial intelligence applications. The course will include a number of programming projects that try to solve specific information-processing demands that occur in particular tasks and simulate human information processing. Student must have taken or currently be taking 15-122 or 15-150. If you will be taking 15-122 or 15-150 as a co req for this course, please contact Emilie O'Leary emilier@andrew.cmu.edu to be registered.
Prerequisites: 15-150 or 15-122

85-219 Foundations of Brain and Behavior

Fall: 9 units
This course provides a general introduction to the neural foundations of behavior. Topics will cover cognitive, perceptual, motor, social, and affective aspects of behavior. Each topic will be addressed at multiple scales, from single neurons and their interactions, to brain systems, to computational principles, and to real-world behaviors. While the focus will be on foundational principles and mechanisms (including some pretty cool case studies, illusions, anecdotes, etc.), there will also be some effort given to integrating current advances in computational cognitive neuroscience, including both the applications of modern AI to understanding biological systems and how principles drawn from biological systems might inform or improve artificial systems. Students are expected to regularly attend and participate in class.

85-221 Principles of Child Development

Fall and Spring: 9 units
This course is about normal development from conception through adolescence. Topics include physical, perceptual, cognitive, emotional and social development. Students will learn facts about children at various points in development, theories about how development works, and research methods for studying development in infants and children. Students will be encouraged to relate the facts, theories and methods of developmental psychology to everyday problems, social issues and real world concerns.

85-232 Thinking in Person vs. Thinking Online

Fall: 9 units
Being online changes how we think. Different media lead us to ask different questions, remember (or forget) different information, attend to different details, and interact with other people in different ways. These types of thinking aren't inherently better or worse, but they may be better or worse for facilitating specific goals. Too often, we use a particular medium/technology without considering how it will influence our thinking. This can lead us to be less efficient or less effective at a task than we otherwise might be, or can qualitatively change the nature of our outcomes. In this class, we will explore how the media we use affects the character of our thinking, so as to enable students to make mindful and deliberate choices about how to interact with media in ways that support the type of thinking desired and appropriate for their goals. Moreover, we will examine how to optimize media for specific goals in important applied domains, such as education, medicine, policy, child-rearing, and dating.

85-241 Social Psychology

Fall and Spring: 9 units
The focus of this course will be on how peoples behavior, feelings and thoughts are influenced or determined by their social environment. The course will begin with lectures and readings on how social psychologists go about studying social behavior. Next, various topics on which social psychologists have done research will be covered. These topics will include: person perception, prejudice and discrimination, the nature of attitudes and how attitudes are formed and changed, interpersonal attraction, conformity, compliance, altruism, aggression, group behavior, and applications of psychology to problems in health care, law, politics, and the environment. Through readings and lectures on these topics, students will also be exposed to social psychological theories.

85-250 Hack Your Life: The Science and Practices of Student Health and Well-Being

All Semesters: 9 units
College offers a new opportunity to hack your life to explore who you are, how you learn, and how you can take better care of yourself. This course will give you the opportunity to fully explore the CMU student experience, the science of learning, and to explore issues central to students (e.g., resilience, social connections, mental health, sleep). Much of this course will focus on providing discussion, strategies, and practices around how you can live a better life, and nurture your happiness and health.

85-251 Personality

Intermittent: 9 units
The primary purpose of personality psychology is to understand human uniqueness and #8212;how and why it is that one person differs from others, in terms of the ways that they thinks, feels, and acts. Students in the course will be exposed to several broad theoretical perspectives, each of which attempts to capture and understand the origins and consequences of individual distinctiveness from a slightly different vantage point. Included among these approaches are the dispositional or trait, psychoanalytic, learning, humanistic, and cognitive self regulation perspectives. This is a survey course and is intended to provide students with a broad background of theory and research in the area. Class meetings consist primarily of lecture, but there is some discussion too. Students will be given the opportunity to assess their own personalities during the course. A consistent theme throughout the course is the relationships between aspects of one's personality and physical health.

85-252 Intro to Health Psychology: SES and Health Inequalities

All Semesters: 3 units
Health Disparities exist in many countries around the world. For years researchers have sought to determine the root cause of these disparities and to explain why some people live significantly longer, healthier lives than others. Both mortality and morbidity rates can be related to ones' place in society and one's interactions with others. This course is designed to critically examine the social factors research has found to impact individual and population health experiences. We will focus specifically on those factors that comprise one's socioeconomic status. Students in the course will learn how money and access to health services are not the only factors that matters when it comes to one's health.

85-258 Intro to Health Psychology: Stigma and Its Consequences

All Semesters: 3 units
This course will introduce students to theoretical and empirical psychological research on prejudice and social stigma. The topics covered will include examinations of why individuals stigmatize: exploring cognitive, evolutionary, self, and system justification explanations. The course will examine the consequences of stigmatization for low-status groups (e.g., stereotype threat, dis-identification, internalization, health outcomes). We will explore the role of stigma in intergroup interactions and variation in the experience of stigma. Specific course topics will include the meaning of stigma, why people stigmatize, the physiological, cognitive-affective and social behavioral processes linking stigma and health outcomes, and moderators of stigma.

85-261 Psychopathology

Intermittent: 9 units
The study of psychopathology is not an exact science; nor are there many clear-cut parameters with which to differentiate "normal" and "abnormal" behavior. This course will focus on learning about and understanding the range of behaviors which fall within the province of "abnormal" psychology. Its approach will be descriptive, empirical, theoretical, and conceptual. Students will examine definitions of "abnormality" in a historical and contemporary context, explore issues relevant to diagnosis and patient care, be introduced to various psychological diagnostic categories, and develop an appreciation of the range of empirically-supported treatments for these disorders.

85-265 Introduction to Research Methods

All Semesters: 9 units
No course description provided.

85-271 Animal Minds

All Semesters: 9 units
With intricate cultures, impressive technology, and layered social lives, humans seem to stand apart from their animal kin. However, humans and non-human animals share many aspects of their mental lives, and, upon closer inspection, some animals even reveal cognitive abilities far beyond the capacities of humans. Through comparing and contrasting human and non-human cognition, we can learn about human psychological uniqueness and its evolutionary origins, and fundamental properties of cognitive processes in general

85-281 Introduction to Clinical Psychology

Spring: 9 units
This course is designed to introduce students to a wide variety of concepts in the area of clinical psychology. We will explore clinical psychology in an historical perceptive, ethics related to the practice of psychology, and various theories of psychotherapy (Incluing psychoanalytic, psychodynamic, existential, and cognitive behavioral). Also, we will look at group theories underlying group therapy and family/systems therapy.
Prerequisites: 85-251 or 85-261

85-294 Teaching Assistantship

Intermittent
This course is designed to provide students with an apprenticeship in the practice of teaching through one-on-one interaction with a faculty member in the design, administration, and teaching of a course. The student should have previous coursework in the topic domain of the course to ensure that they have the basic skills and background necessary to contribute to the course. The Teaching Assistantship will be supervised by a faculty member, and should result in a concrete, measurable contribution to a course (such as the design of assignments or exams) and/or a reflection on the practical and pedagogical considerations of course design (such as a paper). It is the student's responsibility to make independent arrangement for independent course study courses with individual faculty members. This should be done the semester before a student wishes to register for one of these courses. The course may be taken for any number of units up to 9, depending on the amount of work done.

Course Website: https://tinyurl.com/2encx2n3 (https://tinyurl.com/2encx2n3/)

85-300 Introduction to Research Methods

All Semesters: 9 units
The overall goal of this course is to help you transform from being consumers of research knowledge to being evaluators and producers of it. This course provides (a) hands-on exploration of fundamental concepts in research design, statistical analysis, scientific writing, and ethics; (b) skills necessary for designing, conducting, analyzing, and disseminating an observational study; and (c) skills for critically evaluating psychological research and mainstream media reports of it.
Prerequisites: (85-104 or 85-219 or 85-251 or 85-221 or 85-241 or 85-102 or 85-213 or 85-211) and 36-200

85-309 Statistical Concepts and Methods for Behavioral and Social Science

Spring: 9 units
Research in the Social Sciences is a project of understanding the ways in which people are similar while grappling with the ways in which they are different. Statistical methods are a powerful tool for managing the tension between the two. This course introduces the statistical methods most commonly used in in the social sciences, as well as their implementation in the R programming language. Topics involve exploratory data analysis, sampling and randomization, hypothesis testing, and power analysis.
Prerequisites: 36-201 or 36-200

85-310 Research Methods in Cognitive Psychology

Fall and Spring: 9 units
This is a course in which students develop the research skills associated with cognitive psychology and cognitive science. Students learn how to design and conduct experiments, and analyze and interpret the data they collect. The course covers a variety of experimental designs, e.g., factorial, Latin Squares. Analyses of response times, qualitative data, and signal detection are also covered. Cognitive modeling will also be discussed. Topics include mental imagery, memory, and perception. The class format consists of lectures, discussions and student presentations.
Prerequisites: (85-211 and 36-309) or (85-213 and 36-309) or (85-211 and 85-309) or (85-309 and 85-213)

85-311 Research Methods: Meta-Analysis

Intermittent: 9 units
The scientific process is inherently cumulative: Scientific understanding moves forward by building on the theories, methods, and findings of individual research. The broad aim of this course is to teach you a set of practical tools called meta-analysis for synthesizing existing research.
Prerequisites: 85-320 or 85-330 or 85-314 or 85-340 or 85-310 or 85-300

85-314 Cognitive Neuroscience Research Methods

Intermittent: 9 units
This is a hands-on laboratory course designed to foster basic skills in the empirical approaches used in cognitive neuroscience research. Students will learn how to evaluate which cognitive neuroscience method is best suited to a research question, basic experimental design and analysis, and how to formally present empirical results. The course will focus on functional MRI, but will also cover structural MRI (diffusion imaging) and EEG, and survey various other methods. Students will work with actual datasets using the current software used by cognitive neuroscience researchers.
Prerequisites: (36-309 or 85-309) and (85-219 or 85-211)

85-316 Research Methods in Health Psychology

Spring: 9 units
TBA

85-320 Research Methods in Developmental Psychology

Fall and Spring: 9 units
This is a laboratory course, in which the student will have direct experience working with children, as well as writing research reports and designing and critiquing research in child development. The purpose of the course is to develop research expertise that will assist the student both in carrying out research and in evaluating the research of others. Special emphasis will be given to the unique methodological problems associated with the study of development. Students must be sure they are also available to attend the Children's School during specific blocks in addition to the class meeting times. Testing times will be Monday- Thursday with 3 year old testing times being from 8:45-9:30am, 10:20-12:15pm. 4 year old testing times from 8:30-9:15am, 10:05-12:20pm, 1:10-2:20pm. Ks testing times being 8:45-9:45am, 10:15-11:15am,1:15-2:25pm, student need to be available for one time slot from each age.
Prerequisites: (85-309 and 85-221) or (36-309 and 85-221)

85-330 Analytic Research Methods

Intermittent: 9 units
This class will teach students how to apply six major non-experimental research methods used in analytic behavioral analysis. Protocol Analysis. This method is used to study patterns and changes in problem-solving and their matches to theoretical models, including computational models. Corpus Analysis. This method is used to isolate patterns of behavioral and communication usage and change, as revealed through the study of the world-wide web and large computerized databases such as CHILDES, TalkBank, or the British National Corpus. Tools here include text searches and data-mining. Conversation Analysis. This is a microanalytic method used to examine sequencing, repair, and orientation in closely transcribed recordings of spoken interactions, as made available through systems such as the CABank database, as well as recorded programs on YouTube and elsewhere. Coding Systems. This approach seeks to capture interactional and behavioral structures in writing, teaching, interview, and other interactions. Here, there will be a special emphasis on the coding of instructional interactions. Gesture Analysis. This microanalytic method seeks to track patterns in gestural and nonverbal communication, often in association with spoken messages. Profile Analysis. This approach studies differences across learners at various ages and ability levels and group differences involving aphasia, autism, stuttering, dementia, and other individual differences. Students will work with data already available from previous studies, and will also learn to collect their own new datasets. Although the data being examined have been generated through naturalistic processes, they can be analyzed quantitatively using time-series analyses, non-parametric statistics, error matrices, and neural network simulations. In these various analyses, we will also consider how behavioral patterns are shape
Prerequisites: 36-200 or 36-201

85-340 Research Methods in Social Psychology

Fall and Spring: 9 units
This course is designed to provide students with the necessary knowledge to evaluate research, make transitions between theory and the operations that test the theory, and to design and carry out original research. Topics will include the nature of proof and causal inference, manipulation of indepen-dent variables, measurement of dependent variables, questionnaire design, experimental ,and quasi-experimental, design and ethical issues involved in doing research. Survey, observational and experimental techniques as applied in both field and laboratory settings will be covered. Students will be expected to criticize completed research. They are also expected to design measures and complete their own original studies. During the course of the semester students will also be expected to design and carry out an original research project as well.
Prerequisites: (85-251 and 36-309) or (36-309 and 85-241) or (85-309 and 85-241) or (85-309 and 85-241)

85-343 Children, Race, and Racism

Intermittent: 9 units
Millions of children grow up in racialized societies societies that are organized along racial lines historically, politically, and economically. How do children growing up in racialized societies come to understand race? How do children learn racism? How do children develop resilience in the face of racism? These are some of the questions we will address in this course through a combination of reading primary empirical and theoretical articles in psychology and class discussion.
Prerequisites: 85-221 or 85-104 or 85-251 or 85-241 or 85-102 or 85-219 or 85-211

85-345 Meaning in Mind and Brain

Intermittent: 9 units
What does it mean to say that an object, word, event or sentence means something? What is the nature of semantic representations that are activated in the brain during comprehension, and how are they related to perceptual, linguistic, mnemonic and motor representations? How do these representations emerge over the course of development, and how can they be selectively impaired by brain damage? This course examines these and related questions by drawing on findings from a broad range of methodologies, including developmental studies of young children, behavioral studies of adults, neuropsychological studies of brain-damaged patients, neurophysiology and functional brain imaging, and computational modeling. The course will take a seminar format in which students read, present and discuss the current literature.
Prerequisites: 85-213 or 85-211 or 85-219

85-347 Stress and Health Across the Lifecourse

Intermittent: 9 units
This seminar is designed to delve deeper into the topic of stress and health with a life course perspective. The aims of this course is to help students develop the conceptual and methodological skills necessary for interpreting empirical studies (as well as claims in pop culture) in this area of research and to understand the critical roles of time and timing. To facilitate these goals, the course will combine brief lectures, discussion of readings, oral presentations, and writing.

85-350 Psychology of Prejudice

Spring: 9 units
This course is devoted to the study of both traditional and more modern forms of prejudice and discrimination and the psychological processes that can arise from categorizations and stereotyping. The class provides an overview of the cognitive and emotional underpinnings of prejudice and discrimination as it pertains to many forms of inequality. Its goal is to examine social differences and social inequality in many areas of society. The psychological theories underlying these behaviors will be examined as well as their impact on the lives of stigmatized individuals. In addition to the traditional forms of prejudice based on such things as race, gender and age, other inequalities that result from less traditional groupings such as social class, appearance, and disability will be explored. Research on issues of social identity, intergroup relations and the reduction of prejudice will be examined through readings and class activities.
Prerequisite: 85-241

85-351 What is Attention?

Intermittent: 9 units
For over a century, scientists have claimed that no one knows what attention is yet the past half-century has seen over 40 thousand publications with "attention" in the title. What gives? The primary goals of this course are first to show that we know what attention is and second, to demonstrate how to construct an important type of explanation in cognitive science. We investigate classics in the field and engage cutting edge research, in psychology, neuroscience, and even philosophy. One project will be cleaning house (theory and concepts). At the same time, in identifying the functional nature of attention, we unify different levels of analysis to construct a comprehensive account of what attention is, linking behavior, algorithms and neuroscience. We use this account to tackle various issues: different targets and forms of attention, attention and memory, the difference between attention and priming, attention's relation to behavior, attention and consciousness, executive control, attention's dependence on reward and learning, the developmental biology of attention, disorders of attention, attention and expertise, attention and implicit bias among other topics. Attention forms the foundation of our understanding of many other areas (arguably, it forms the foundation of life). The course will be based on drafts of the forthcoming second edition of the instructor's book, Attention (Routledge, 2014). We will also, hopefully, have guest lecturers from outside of CMU.
Prerequisites: 85-211 or 85-219

85-352 Evolutionary Psychology

Intermittent: 9 units
This course will cover both the fundamentals of evolutionary psychology, including the theories of natural and sexual selection, with the overarching aim of providing an overview of the field at an advanced level. We will examine the relevance of evolutionary thinking to a range of psychological phenomena including problems of survival, long-term mating strategies, short-term sexual strategies, parenting, kinship, cooperative alliances, aggression and warfare, conflict between the sexes, and prestige, status, and social dominance. We will also examine evolutionary approaches to sensation and perception, development, consciousness, cognition, language, and abnormal behavior. Juniors and Seniors only or permission of instructor. Pre req: 85-102, 85-211, 85-221, 85-241 or 85-251
Prerequisites: 85-102 or 85-211 or 85-251 or 85-241 or 85-221

85-353 Mindfulness: Science and Practice

Intermittent: 9 units
This course will focus on blending first-person experience with mindfulness practices (including mindfulness meditation) and learning about the scientific research on mindfulness. Students will engage in guided mindfulness exercises, develop a daily mindfulness practice, and try out different mindfulness training traditions. In addition, much of this course will be focused on applying a critical eye to the theory, measures, mechanisms, and effects of mindfulness (and mindfulness training interventions) across multiple domains cognition, social processes, behavior, biological mechanisms, and health. As such, this will be a small seminar course focused developing first-person experiences of mindfulness and on discussing the debates and opportunities related to the emerging science of mindfulness.
Prerequisites: 85-340 or 85-310 or 85-320 or 85-314

85-354 Infant Language Development

Intermittent: 9 units
While adults struggle to learn languages, almost all infants acquire language with seemingly little effort. This course examines infants' learning abilities and language milestones with a focus on several different theoretical accounts of language development, and the way empirical data can be used to assess those theories. The course is reading intensive, and evaluation will be based on both written assignments and oral participation.
Prerequisites: 85-211 or 85-221

85-356 Expertise: The cognitive (neuro)science of mastering almost any skill

Intermittent: 9 units
Though some of us struggle to hold a phone number in memory long enough to dial, Lu Chao recited 67,890 digits of pi from memory in 2005. With effort and effective strategies, human perception and cognition can reach great heights. But, even without much intentional practice, most people effortlessly recognize lyrics from hundreds of songs and faces of thousands of people. How does the human brain develop expertise across domains as diverse as music perception and performance, memory, sports, face recognition, and skills like chess? How do experts 'hack their brain' to achieve unusual levels of performance? Is talent made, or is it inborn? Can we capitalize on cognitive science and neuroscience to become better at math, wine tasting, medical diagnosis, or computer programming? In this course, we will work together to answer these questions while learning how to critically evaluate, synthesize, and communicate peer-reviewed research.

Prerequisites: 85-211 or 85-219

85-357 Navigating Race and Identity in America: The Role of Psychology in Racial Intera

Intermittent: 9 units
How have social institutions and historical factors led to the belief systems and stereotypes that shape how race is experienced in American society, and how do these belief systems affect the way individuals within racial groups come to view and define themselves? This course will serve as an introduction to how people's psychologyhow they think, feel, and actshapes their experience of race and identity in America. After a brief discussion about the structural and systemic origins of the racial status quo, we will examine the way that individuals navigate the social and racial landscape of modern-day America. Complementing courses that take sociological approaches to race in America, this course will focus on how individuals' perceptions and thoughts about the world affect how they interpret and respond to social situations. For example, the course will address: how stereotypes about one's race or identity can cause individuals to feel threatened, and can undermine health, feelings of belonging, and academic performance how an individual's concerns about the thoughts and beliefs of others can radically affect identity formation, particularly during adolescence how individuals have to navigate multiple cultural identities, especially as minority group members contending with mainstream ideas that differ from their own how majority group members (e.g., Whites) view their role in racial systems, and how they deal with concerns about being or appearing prejudiced how interventions can use social psychological concepts to mitigate negative outcomes of racial inequality We will then use our understanding of these concepts to examine and consider different racial situations thoughout American society and to understand how individuals navigate and experience race and identity. Throughout the course, we will watch films, read literature, and analyze music and art that reflect the experience of race and identity.

85-358 Pro-Social Behavior

Fall: 9 units
This course is an advanced seminar that focuses on social psychological research involving the examination of pro-social behavior. A heavy emphasis will be placed on classic research on helping (which investigates how, when, and why we help strangers), as well as the wide body of literature on social support (which investigates how we help, and seek help from, those who are closer to us). Research on both help-seeking and help-provision will be covered, as well as the implications of this type of pro-social behavior for relationships and health. The course also will cover research on other types of pro-social behavior such as empathy, altruism, forgiveness, and cooperation. This is an advanced seminar in which you will be expected to read original research articles and chapters on assigned topics and come to class prepared to discuss the material. Readings will consist of theoretical and empirical articles from psychology journals and related sources. Additional course requirements will involve short, weekly writing assignments, student presentations of research articles, and a written research proposal. Over the course of the semester, students will design and carry out a small-scale, original investigation on a topic of interest.
Prerequisites: 85-330 or 85-340 or 85-314 or 85-320 or 85-310 or 85-311

85-359 Introduction to Music Cognition Research

Intermittent: 9 units
This course explores the roles of cognitive processes in the experience of music with a focus on carrying out a collaborative laboratory project in order to understand first-hand the challenges of the experimental study of music. In readings, lectures, discussions, and demonstrations we will become acquainted with the relevant psychological theories of perception, memory and learning, and review and critically analyze selected experimental findings on the psychology of music. We will examine the use of psychological principles (e.g. Gestalt laws of perception, limitations on working memory, categorical perception, chunking, schemas, modularity) to explain musical phenomena. The emphasis will be on applying an experimental approach to music perception and cognition, but we will also consider ongoing debates about larger issues (such as musics adaptive value to the human species, and the determinants of musical taste).
Prerequisite: either Harmony 1 or Cognitive Psychology or introduction to psychology or an intro level statistics or by instructor permission.
Prerequisites: (36-200 and 85-102) or (36-200 and 85-211)

85-360 Origins of Intelligence

All Semesters: 9 units
The nature and origins of human intelligence is a much-debated topic. Questions about the evolution and development of intelligence in humans, how intelligence compares among animals, the basis of intelligence in the brain, how to create intelligence in machines, the role of genes and experience, and individual variability in intelligence are all areas of vigorous scientific inquiry. Popular "folk" views of intelligence (that may be misguided or incorrect) have shaped all levels of society from parenting to politics. There is no universally accepted definition of human intelligence but one conceptualization is 'the ability to remember, reason, plan, and solve novel problems". This course will explore scientific and popular views of the origins of intelligence. The approach will be to read popular science articles and books that deal with intelligence in humans, animals, and machines and locate the primary scientific work on which those claims are made in order to evaluate the rigor and validity of intelligence theories. The course assignments will primarily consist of oral and written critiques of theories and data on the science of intelligence.

85-362 Seminar on Addiction

Intermittent: 9 units
This seminar will explore various topics central to the study of drug addiction, with a primary emphasis on psychological and neurobiological theories of drug addiction. We will also discuss research and clinical techniques related to the assessment, diagnosis, and treatment of substance use disorders and related problems. Emphasis will be on alcohol and tobacco, but other drugs will be discussed as well. The main course objective is to provide a unifying model for understanding the fundamental aspects of addiction.
Prerequisites: 85-310 or 85-340 or 85-320 or 85-314

85-363 Attention, Its Development and Disorders

Intermittent: 9 units
TThis seminar will discuss a broad range of topics pertaining to the study of human attention, including: theoretical frameworks and biological foundations of human attention; interrelationship between attention and other aspects of cognition (such as perception, memory, and executive functions); development of attention in infancy and childhood; biological and psychological foundations of attention disorders. Students will be expected to read original research articles, lead and participate in class discussions, and complete a term paper.
Prerequisites: 85-221 or 85-211

85-370 Perception

Fall: 9 units
Perception, broadly defined, is the construction of a representation of the external world for purposes of thinking and acting. Although we often think of perception as the processing of inputs to the sense organs, the world conveyed by the senses is ambiguous, and cognitive and sensory systems interact to interpret it. In this course, we will examine the sensory-level mechanisms involved in perception by various sensory modalities, including vision, audition, and touch. We will learn how sensory coding interacts with top-down processing based on context and prior knowledge and how perception changes with learning and development. We will look at methods of psychophysics, neuroscience, and cognitive psychology. The goals include not only imparting basic knowledge about perception but also providing new insights into everyday experiences.

85-375 Crosscultural Psychology

Intermittent: 9 units
Human beings share a common genetic inheritance, but our cultural institutions differ in a bewildering variety of ways. This course explores the many different cultural expressions of basic human cognitive and social abilities and needs, We will look at cultural variations in child rearing, mother-child attachment, language socialization, categorization, reasoning, problem-solving, architecture, music, politics, warfare, food-gathering, sex roles, mental disorders, and altered states of consciousness, all with the goal of understanding how the shape of social systems and symbolic expression reflects the economic and adaptive needs of the culture and its people. Among the approaches to these phenomena we will consider are symbolic interaction, cognitive anthropology, dialectic materialism, and modern ethnology.
Prerequisites: 85-211 or 85-198 or 85-102 or 85-100 or 85-219 or 85-241 or 85-221 or 85-261 or 85-251

85-377 Attitudes and Persuasion

Intermittent: 9 units
This advanced undergraduate course will focus on the topic of attitude change and how various persuasive techniques are used to shape human response. The dynamics of propaganda and what makes the techniques effective on social and consumer decisions will be addressed. The primary goals of the course are to 1) understand the dynamics of attitude change; 2) explore the mechanism by which attitude change techniques operate and 3) examine relevant theories and research in persuasion. Examples of topics covered include the origins of attitudes, how attitudes influence judgments, social power and attitude change, and how individual decisions are influenced by the mass media. Classic and contemporary research in the area of persuasion will be examined in the form of course readings and assignments.
Prerequisite: 85-241

85-380 In Search of Mind: The History of Psychology

Intermittent: 9 units
This course will focus on three aspects of the origin and growth of experimen-tal psychology. The first is the prehistory of psychology, where the connection of the discipline to the development of modern science, and in particular, its origins in philosophy and physiology, is examined. The second focus of the course is on the different approaches and attempts to define the field that have contested for dominance during much of the life of the discipline. The final major focus of the course is on the modern period (roughly the last forty years) where the influences that brought about the modern counter-revolution in psychology will be examined, and where some conjecture about likely future directions will occur. Two prior courses in psychology.

85-382 The Psychology and Neuroscience of Consciousness

Intermittent: 9 units
This course will explore consciousness as a scientific problem. It aims to dispel obscurity and mystery to make clear how consciousness can be illuminated empirically and theoretically without losing site of the "phenomenal". We begin with isolating the basic phenomenon, delve into the conceptual and philosophical background dividing access from phenomenal consciousness, and discuss methods for tracking consciousness. We will then identify two clear questions about 'generic' and 'specific' consciousness. On generic consciousness, we shall explore a set of empirical theories of consciousness and the evidence that supports them. This will include recurrent processing theory, global workspace theory, and higher-order theory among others. On specific consciousness, we will look at neural correlates and experimental interventions to test causal claims about how consciousness arises from the brain, with specific emphasis on sensory consciousness and the role of information and representation. Special topics will likely include the attention in consciousness, consciousness and agency, vegetative state, unconscious sensory processing in normal and lesioned brains, split brain phenomena and abnormal consciousness in psychiatric disorders such as schizophrenia. If possible, we will have a few guest lectures by local experts.
Prerequisites: 85-213 or 85-211 or 85-219

85-385 Auditory Perception: Sense of Sound

Intermittent: 9 units
This course explores how our sense of hearing allows us to interact with the world. Students will learn about basic principles of sound, spatial sound, sound quality, hearing impairment, auditory perception, interactions with other modalities, and auditory cognition. Topics may also include musical acoustics, basic auditory physiology, sound-semantic associations, acoustic analysis, and sound-making gestures. We will consider not only simple laboratory-generated signals, but also more complex sounds such as those in our everyday environment, as well music and speech. Students will gain some in-class experience with generating sounds and analytic listening. After students reach a sophisticated level of understanding of the auditory fundamentals, they will apply their knowledge to the study of several current issues in auditory research.
Prerequisites: 85-102 or 85-211

85-391 Psychology of Sleep

Intermittent: 9 units
This course is ONLY offered at Carnegie Mellon in Qatar. This course is an advanced seminar that focuses on the biology, psychology, and social factors of sleep and dreaming. The course will go over the history behind the scientific study of sleep, as well as the cultural and psychological underpinnings of dreaming. Students will also delve into the neuroscience and abnormal psychology of sleep. Emphasis will be placed on reading, presenting and analyzing empirical research articles. Students will also be required to fill out sleep logs and a dream diary, culminating in a final research paper analyzing their semester long sleep patterns and dreams based on research discussed in class.
Prerequisites: 85-102 and 85-211

85-392 Human Expertise

Intermittent: 9 units
The process of becoming an expert involves many changes, some quantitative and some qualitative. This course will provide an up-to-date account of the theory and data concerning the development of expertise. Questions addressed include the following. What does it take to become an expert? Are experts born or made? Is the process of acquiring expertise common across different domains from music to sports to science? Research studied in the course will employ a variety of methodologies, from case studies to protocol analysis to computational modeling.
Prerequisites: 85-211 or 85-213

85-393 Memory: Models & Mechanisms

Intermittent: 9 units
This course will provide a basic understanding of human memory, covering both the many phenomena that have been studied over the years and also how theories have placed these phenomena within a general human cognitive system. The course will treat data and theory as equally important. Theory without empirical evidence is vacuous. Data without an explanatory mechanism is also unsatisfying. The course will cover many of the major principles of human memory starting with how information from the environment is encoded, processed and stored in memory. We will focus on how working memory (think of it as the Human CPU) affects how we encode and retrieve information from memory and what the limits are on this processing machinery. Theories of learning and the mechanisms involved in acquiring information as well as theories of forgetting will be examined in depth, along with variables that affect ease of encoding and obstacles to retrieval. The course will also focus on illusions of memory, how and why human memory is vulnerable to illusions and produces memory distortions. Most phenomena will be discussed in the context of theoretical explanations. Students will also learn about modeling approaches and how the various phenomena have been understood with different theoretical accounts. As a final project each student will develop a model to account for a phenomenon. This will either be fit to an existing body of data, or will take an existing theory, generate a new prediction based on that theory, and design an experiment to test whether the theory is supported or not (the experiment will not be run, but the design and predictions should be clear enough that it could be).
Prerequisite: 85-219

85-394 Development in Context: Applying Theory and Research to Support Thriving

Intermittent: 9 units
This course is an advanced seminar that focuses on synthesizing theory and research in developmental psychology and learning sciences so that proposed interventions to support children's development can be designed and evaluated. Theory and research relevant to cognitive, social emotional, and physical development can be applied to facilitate children's thriving in learning, belonging, mental health, and physical health, etc. Students will have an opportunity to select a particular age group and context for focus of independent literature review, a midterm interview project, and a final proposal for research-based intervention.

85-395 Applications of Cognitive Science

Spring: 9 units
The famous psychologist George Miller once said that Psychology should "give itself away." The goal of this course is to look at cases where we have done so and #8212; or at least tried. The course focuses on applications that are sufficiently advanced as to have made an impact outside of the research field per se. That impact can take the form of a product, a change in practice, or a legal statute. The application should have a theoretical base, as contrasted, say, with pure measurement research as in ergonomics. Examples of applications are virtual reality (in vision, hearing, and touch), cognitive tutors based on models of cognitive processing, phonologically based reading programs, latent semantic analysis applications to writing assessment, and measurses of consumers' implicit attitudes. The course will use a case-study approach that considers a set of applications in detail, while building a general understanding of what it means to move research into the applied setting. The questions to be considered include: What makes a body of theoretically based research applicable? What is the pathway from laboratory to practice? What are the barriers - economic, legal, entrenched belief or practice? The format will emphasize analysis and discussion by students.
Prerequisites: 85-251 or 85-102 or 85-241 or 85-221 or 85-211 or 85-219 or 85-104

85-401 Introduction to Noninvasive Brain Imaging

Spring: 9 units
In the past the understanding of the brain's structure and function was limited by the need to access the brain via surgery and postmortem examination. In recent decades, advances in the fields of biology, psychology, physics, and engineering, have led to a slew of noninvasive methods for looking at the brain structure and function. These methods have become widespread in both clinical and research settings. This course will provide a survey of some of the most prominent of these neuroimaging methodologies, their advantages and disadvantages, and examples of their use. Topics covered include electroencephalography (EEG), computed tomography (CT), functional near-infrared spectroscopy (fNIRS), positron emission tomography (PET) and magnetic resonance imaging (MRI). Pre reqs listed or by permission of the course instructor.
Prerequisites: 03-121 or 85-219 or 85-102 or 03-151

85-402 Multilevel Modeling

Intermittent: 9 units
This course introduces a number of expressions of multilevel modeling that are now in common use in all the major branches of psychology, as well as in education and other sciences. The course balances conceptual understanding of MLM with practical, lab-based application. A working knowledge of R or SAS statistical software will be advantageous but not required.
Prerequisites: 36-309 or 85-309

85-406 Autism: Psychological and Neuroscience Perspectives

Fall: 9 units
Autism is a disorder that affects many cognitive and social processes, sparing some facets of thought while strongly impacting others. This seminar will examine the scientific research that has illuminated the nature of autism, focusing on its cognitive and biological aspects. For example, language, perception, and theory of mind are affected in autism. The readings will include a few short books and many primary journal articles. The readings will deal primarily with autism in people whose IQ's are in the normal range (high functioning autism). Seminar members will be expected to regularly enter to class discussions and make presentations based on the readings. The seminar will examine various domains of thinking and various biological underpinnings of brain function, to converge on the most recent scientific consensus on the biological and psychological characterization of autism. There will be a special focus on brain imaging studies of autism, including both structural (MRI) imaging of brain morphology and functional (fMRI and PET) imaging of brain activation during the performance of various tasks.
Prerequisites: 85-429 or 85-219 or 85-213 or 85-211 or 85-355

85-407 How the Brain Makes Meaning

Intermittent: 9 units
Conceptual knowledge underpins all aspects of everyday experience, from language, to thinking, to recognizing familiar objects, people and places. This seminar will survey major theories and findings about how the brain represents 'meaning.' The course will emphasize research using neuropsychological methods in brain-damaged patients and functional neuroimaging in healthy participants. Students will read primary empirical and theoretical review articles to develop an understanding of both classic findings and recent discoveries about how the human brain represents meaning.
Prerequisites: (85-219 or 85-211) and (36-201 or 36-200)

85-408 Visual Cognition

Intermittent: 9 units
Recognizing an object, face or word is a complex process which is mastered with little effort by humans. This course adopts a three-pronged approach, drawing on psychological, neural and computational models to explore a range of topics including early vision, visual attention, face recognition, reading, object recognition, and visual imagery. The course will take a seminar format.
Prerequisites: 85-213 or 85-211 or 85-219

85-409 Stigma and its Consequences

All Semesters: 9 units
This seminar will introduce students to theoretical and empirical psychological research on prejudice and social stigma. The topics covered will include examinations of why individuals stigmatize: exploring cognitive, evolutionary, self, and system justification explanations. The course will examine the consequences of stigmatization for low-status groups (e.g., stereotype threat, dis-identification, internalization, health outcomes). We will explore the role of stigma in intergroup interactions and variation in the experience of stigma. Specific course topics will include the meaning of stigma, why people stigmatize, the physiological, cognitive-affective and social behavioral processes linking stigma and health outcomes, and moderators of stigma.

85-412 Cognitive Modeling

Spring: 9 units
This course will be concerned with modeling of agent behavior in a range of applications from laboratory experiments on human cognition, high-performance simulations such as flight simulators, and video game environments. The first half of the course will teach a high-level modeling language for simulating human perception, cognition, and action. The second half of the course will be a project in which students develop a simulated agent or agents for the application of their choice.
Prerequisites: 15-251 or 15-210 or 15-150 or 15-122

85-414 Cognitive Neuropsychology

Spring: 9 units
This course will review what has been learned of the neural bases of cognition through studies of brain-damaged patients as well as newer techniques such as brain stimulation mapping, regional metabolic and blood flow imaging, and attempt to relate these clinical and physiological data to theories of the mind cast in information-processing terms. The course will be organized into units corresponding to the traditionally-defined subfields of cognitive psychology such as perception, memory and language. In each area, we will ask: To what extent do the neurological phenomena make contact with the available cognitive theories? When they do, what are their implications for these theories (i.e., Can we confirm or disconfirm particular cognitive theories using neurological data?)? When they do not, what does this tell us about the parses of the mind imposed by the theories and methodologies of cognitive psychology and neuropsychology?
Prerequisites: 85-219 or 85-211

85-417 Multilingual Minds and the Brain

Fall: 9 units
Does multilingualism change your mind, literally and figuratively? In this course, we will examine several topics related to the differences between mono- and multilinguals. First, how juggling several languages in one brain may "train" certain skills so the multilingual mind processes information differently, even when that information is not language related. Second, how patterns of neural activation may also differ in mono- and multilinguals, changing language processing at that level. Third, how contexts of use and acquisition of different languages may affect how we process information in each one, changing how one makes decisions in each language they speak. We will use original sources to try and answer that initial question. Further, we will analyze published research and propose ways of developing it further.
Prerequisites: 85-320 or 85-340 or 85-330 or 85-310 or 85-309 or 36-309

85-418 Infant development: Inside the Mind of Babies

Intermittent: 9 units
This course will provide an overview of development in infancy with a focus on the emerging mind. A basic knowledge of developmental issues is assumed. We will cover the key aspects of infancy but with a primary focus on perception (seeing), cognition (thinking), and action (doing). Each week, students will be required to read a chapter in a textbook as well as short advanced empirical paper, often with conflicting accounts of a phenomenon. The instructor will introduce the key concepts, issues, and lines of research, but in each case students are expected to take an active role in discussing and developing ideas about the topic under consideration. Research methods specific to the study of infant development will be emphasized. Major issues that will be discussed include theories of developmental change, continuity in development, the nature of the psychological mechanism that underpin change, the relative contributions of heredity and environment, and the notion that all change occurs through a series of development cascades.
Prerequisite: 85-221

85-419 Introduction to Parallel Distributed Processing

Spring: 9 units
This course provides an overview of Parallel-Distributed-Processing/neural-network models of perception, memory, language, knowledge representation, and learning. The course consists of lectures describing the theory behind the models as well as their implementation, and their application to specific empirical domains. Students get hands-on experience developing and running simulation models.
Prerequisites: 21-112 or 21-120 or 21-111 or 21-115 or 21-124

85-421 Language and Thought

Intermittent: 9 units
This course allows the student to explore ways in which the mind shapes language and language shapes the mind. Why are humans the only species with a full linguistic system? Some of the questions to be explored are: What kinds of mental abilities allow the child to learn language? What are the cognitive abilities needed to support the production and comprehension of sentences in real time? How do these abilities differ between people? Are there universal limits on the ways in which languages differ? Where do these limitations come from cognition in general or the specific language facility? Why is it so hard to learn a second language? Are there important links between language change and cultural change that point to links between language and culture?
Prerequisites: 80-150 or 85-213 or 85-211 or 80-180

85-422 Clinical Psychology: Science and Practice

Spring: 9 units
In this course, students will be exposed to the science and practice of clinical psychology, with a particular emphasis on the synergistic relationship between clinical psychological research and clinical practice. We will focus on the four major activities that clinical psychologists engage in (research, assessment, diagnosis, and psychotherapy). Students will learn about the clinical characteristics of major psychological disorders and the empirically-validated treatments available for these conditions. We will make frequent use of research findings and the scientific method to evaluate and understand concepts in clinical psychology. Critical thinking will be emphasized as we explore the scientific strengths and limitations of various treatments for psychological disorders. This course is designed to be a smaller seminar course for juniors and seniors considering graduate school in clinical psychology.
Prerequisites: 85-261 or 85-310 or 85-340 or 85-314 or 85-104 or 85-320

85-423 Cognitive Development

Intermittent: 9 units
The general goals of this course are that students become familiar with the basic phenomena and the leading theories of cognitive development, and that they learn to critically evaluate research in the area. Piagetian and information processing approaches will be discussed and contrasted. The focus will be upon the development of childrens information processing capacity and the effect that differences in capacities have upon the childs ability to interact with the environment in problem solving and learning situations.
Prerequisite: 85-221

85-424 Hemispheric Specialization: Why, How and What?

Intermittent: 9 units
The brain is divided into two hemispheres, raising a host of questions about brain organization, hemispheric specialization and laterality. Despite all the research devoted to these questions, our understanding of the behavioral significance and neural basis of laterality remains limited. This course will address the questions of "why", "how" and "what". We will review the latest data and empirical results but will also develop a coherent theoretical perspective, moving from molecular, genetic and evolutionary considerations to cognitive and clinical factors in the understanding of one of the most fascinating phenomena in neuroscience, neuropsychology, psychiatry, neurology, and cognitive sciences. In addition to tackling a major text in the field (The Two Halves of the Brain Edited by Hugdahl and Westerhausen), we will read the latest papers in the field. The class will be almost entirely discussion-based and students will be responsible for doing the readings ahead of time and being prepared for the discussion.
Prerequisites: 85-251 or 85-221 or 85-241

85-425 Child Psychopathology and Treatment

Intermittent: 9 units
The first half of this course will focus on understanding the etiology and epidemiology of child and adolescent psychopathology. Special emphasis will be placed on conditions that are first diagnosed during childhood (e.g., ADHD, Autism, Eating Disorders) as well as understanding how child and adult psychopathology differ. The second half of this course will focus on treatment interventions for youth with psychopathology. Students will learn about how interventions for adults with psychopathology are altered to be developmentally appropriate for children, and methods of intervention commonly used with children but less so with adults(e.g., family therapy, play therapy). For students who have completed abnormal psychology and the psychology breadth requirement but not the other course pre-requisite, 85102, please see Theresa Kurutz to register for this course in BH 343.
Prerequisites: 85-261 and 85-102

85-426 Learning in Humans and Machines

Spring: 9 units
This course explores how probabilistic methods can help to explain cognition and to develop intelligent machines. The applications discussed include perception, language, memory, categorization, reasoning, decision-making, and motor control.
Prerequisite: 15-112

85-427 Metacognition: thinking about one's own thinking

Intermittent: 9 units
The course focuses on understanding metacognition, the marvelous ability of humans to inspect, understand, and regulate their own cognition. How do we know what we do or do not know? How good are we at estimating the accuracy of our memories of the past? How about what we will remember or forget in the future? Can we use such knowledge to do better? The study of metacognition provides an answer to these and many more questions. In other words, metacognition is the path to better knowing yourself.
Prerequisites: 85-211 or 85-219

85-429 Cognitive Brain Imaging

Spring: 9 units
This seminar will examine how the brain executes higher level cognitive processes, such as problem-solving, language comprehension, and visual thinking. The topic will be addressed by examining what recent brain imaging studies can tell us about these various kinds of thinking. This new scientific approach has the potential of providing important information about how the brain thinks, indicating not only what parts perform what function, but also how the activity of different parts of the brain are organized to perform some thinking task, and how various neurological diseases (e.g. aphasia, Alzheimer's) affect brain activity. A variety of different types of thinking will be examined, including short-term working memory storage and computation, problem solving, language comprehension, visual thinking. Several different technologies for measuring brain activity (e.g. PET and functional MRI and also some PET imaging) will be considered, attempting to relate brain physiology to cognitive functioning. The course will examine brain imaging in normal subjects and in people with various kinds of brain damage.
Prerequisites: 85-419 or 85-414 or 85-412 or 85-213 or 85-211

85-432 Data Science for Psychology and Neuroscience

Intermittent: 9 units
This course will cover advanced topics in statistics and experimental design necessary for applied research in modern psychology, including information design, exploratory data analysis, data visualization, nonparametric statistics, data and inference errors (multicollinearity, overfitting, Simpson's and Robinson's paradox), sanitization (data anonymization, de-identification), and linear models (including conditional process models). Students will get hands on experience with simulating, analyzing, and visualizing data in the R statistical environment.
Prerequisites: 85-309 or 36-309

85-435 Biologically Intelligent Exploration

Intermittent: 9 units
Humans and other mammals exhibit a high degree of control when selecting actions in noisy contexts, quickly adapting to unexpected outcomes in order to better exploit opportunities arising in the future. This course will explore both the cognitive and neurobiological systems of adaptive decision-making, through a mixture of readings, lectures, and hands-on modeling projects (in Python and Matlab).
Prerequisites: (85-211 or 85-213) and (21-111 or 21-115 or 21-120)

85-438 Educational Goals, Instruction, and Assessment

Fall: 9 units
This course will meet in TQ 1308 The aim of this course is to teach students how to develop educational goals based on a detailed task analysis of the knowledge, skills, and dispositions required for mastery of a particular aspect of a domain. Goals for early childhood, elementary, middle school, and high school will be discussed and related to the state and national standards. A comprehensive understanding of student achievement will be developed. The importance of matching the instructional program and its assessment to goals will be discussed and demonstrated. Assessment that focuses on covering the full range of specified goals will be studied along with diverse approaches for valid assessment. Other topics include making instructional material choices, funding, classroom management, ethics, and relation to system-level policies. Assignments will emphasize linking goals - instruction assessment. A term project will consist of an in-depth study of one central unit in a discipline or grade level. This course will meet in TQ 1308

85-442 Health Psychology

Intermittent: 9 units
This course is concerned with how behavior and psychological states influence the development of and recovery from disease. The class provides an overview of existing psychological and epidemiological data on the relationship between behavior and disease and addresses the issue of how behavior, emotion and cognition can influence the disease processes. Topics include: measures and concepts, stress and disease, stress and coping, personal control, helplessness and disease, social support and health, reactivity to stress, behavior and hypertension, coronary heart disease, infectious diseases and immune function, and the effectiveness of behavioral interventions in health.
Prerequisites: 36-200 and (85-221 or 85-219 or 85-211 or 85-102 or 85-104 or 85-251 or 85-241)

85-443 Social Factors and Well-Being

Intermittent: 9 units
This course will focus on the role that our social environment plays in our feelings of well-being and in the maintenance of our mental and physical health. Topics to be discussed include marriage, widowhood, loneliness, social support, social participation, social aspects of personality (e.g., social anxiety, extraversion, agreeableness, and hostility), social stressors (betrayal and conflict), discrimination, and socioeconomic status. We will consider how each social factor develops, the extent to which we can alter it or its effects on our lives, and how it influences our overall well-being.

85-444 Relationships

Fall: 9 units
The primary goal of this course is to introduce you to social psychological theory and research on the topic of relationships. Although a variety of relationship phenomena will be discussed, a heavy emphasis will be placed on research that addresses fundamental processes in close relationships. The coverage of material will include a review of historical roots and classic approaches to the scientific study of relationships, as well as exciting new research and theory on particular subtopics. The majority of class time is spent discussing and evaluating recent research. Special emphasis also is given to learning and critically evaluating the methodological tools that are used to study close relationships. This is an advanced seminar in which students will be expected to read original research articles and chapters on assigned topics and come to class prepared to discuss the material. Readings will consist of theoretical and empirical articles from psychology journals and related sources. Additional course requirements will involve short, weekly writing assignments, student presentations of research articles, and a written research proposal. Over the course of the semester, students will design and carry out a small-scale, original investigation on a relationships topic of interest.
Prerequisites: 85-330 or 85-314 or 85-311 or 85-310 or 85-320 or 85-300 or 85-340

85-446 Psychology of Gender

Spring: 9 units
This course is devoted to the investigation of psychological gender rather than biological sex. That is, sex differences will be explored from a social psychological (e.g., socialization) perspective. Implications of both male gender role and female gender role in the areas of relationships and health will be the course focus.
Prerequisites: 85-241 or 85-251

85-480 Internship in Clinical Psychology

All Semesters
This course allows students to gain applied clinical experience in a mental health setting. Students will work alongside psychology professionals at designated field placements. This course is designed to help students apply and expand their knowledge of clinical psychology and to develop appropriate professional work standards. Students will spend the majority of their time (8 hours per week) in an applied clinical setting, with a one hour per week supervision meeting with Dr. Creswell. Instructor permission is required, 85-104 Psychopathology can be taken as either a pre req or a co req. Please contact Dr. Kasey Creswell.
Prerequisites: 85-261 Min. grade B or 85-104 Min. grade B

85-481 Seminar in Intervention

Intermittent: 9 units
This course is an introduction to the therapeutic process. Students will be introduced to a variety of therapeutic approaches and techniques (e.g. Solution-Focused, Cognitive, Client Centered, etc.) and will have the opportunity to learn the basic skills associated with each (e.g. Cognitive Restructuring, Mirroring, Empathic Highlighting, etc.). Instruction will entail a mix of discussion and demonstration, and there will be a heavy emphasis on in-class practice of these skills.

85-482 Internship in Psychology

Fall and Spring
The Internship in Psychology is designed to enable students to gain experience in professional settings related to their studies in Psychology and earn credit for the intellectual work involved. It is the students responsibility to locate an internship site and on-site supervisor, as well as to identify a CMU faculty sponsor. The student registers for the internship by submitting a completed internship form to Emilie O'Leary emilier@andrew.cmu.edu.

85-483 Internship in Psychology - Mini

Fall and Spring
The Internship in Psychology is designed to enable students to gain experience in professional settings related to their studies in Psychology and earn credit for the intellectual work involved. It is the students responsibility to locate an internship site and on-site supervisor, as well as to identify a CMU faculty sponsor. The student registers for the internship by submitting a completed internship form to Lauren McCarthy (laurenmc@andrew.cmu.edu).

85-484 Practicum in Child Development

Fall and Spring
This guided field experience is designed to help students deepen their understanding of developmental psychology by assisting in a preschool or kindergarten classroom and discussing the ways that their experiences relate to the theories they have learned previously and to new readings. Each student will individually schedule a consistent 6 hours per week helping in a Children's School classroom (preferably 2 or 3 chunks of time). Classroom duties will include working one-on-one and with small groups of students as they do puzzles, art projects, dramatic play, etc., as well as helping with snack, playground supervision, classroom cleanup, and storytime. Each student will be expected to keep a journal 1) relating general experiences to developmental theories and 2) documenting the development of a particular child during the semester. All students will meet for a 1 hour weekly discussion with the director. Discussion topics and related readings will be selected collaboratively, based on issues/questions raised by the group's observations and discussions. This course is typically 9 units, but may be negotiable between 3 and 9.
Prerequisite: 85-221

85-501 Readings in Developmental psychology

Intermittent: 9 units
tba please reach out to Emilie O'Leary emilier@andrew.cmu.edu

85-505 Readings In Psychology

All Semesters
As the name implies, the emphasis in the Reading course is on reading articles and books in some specified area. The students work in the course must lead to the production of a written paper which will be read by the instructor directing the readings. Often the reading is related to a research project which the student may wish to conduct. Readings courses have also been used to give students an opportunity to receive instruction in areas which are not included elsewhere in our course listing. The course may be taken for any number of units up to 9, depending upon the amount of work to be done.

85-506 Readings in Psychology

Fall and Spring
As the name implies, the emphasis in the reading course is on reading articles and books in some specified area. The students work in the course must lead to the production of a written paper which will be read by a psychology faculty instructor directing the readings. Often the reading is related to a research project which the student may wish to conduct. Reading courses have also been used to give students an opportunity to receive instruction in areas which are not included elsewhere in our course listing. The course may be taken for any number of units up to 9, depending upon the amount of work to be done. This course is special permission and can only be added in consultation with a psychology faculty member and registered by the Undergraduate administrator, Emilie O'Leary emilier@andrew.cmu.edu.

85-507 Research in Psychology

Fall
This course may include field study, applied work, or laboratory research. The student should have previous training in the basic research skills that will be used in his/her project, especially statistical methods and experimental design. Independent Research Projects will be supervised by a faculty member and must result in a written paper. It is the students responsibility to make arrangements for independent study courses with individual faculty members. This should be done the semester before a student wishes to register for one of these courses. The course may be taken for any number of units up to 12, depending upon the amount of work to be done. Please contact the CMU psychology faculty member you wish to work with to get approval to enroll then email Emilie Rendulic at emilier@andrew.cmu.edu in order to be registered for the course.

85-508 Research in Psychology

Spring
This course may include field study, applied work, or laboratory research. The student should have previous training in the basic research skills that will be used in his/her project, especially statistical methods and experimental design. Independent Research Projects will be supervised by a faculty member and must result in a written paper. It is the students responsibility to make arrangements for independent study courses with individual faculty members. This should be done the semester before a student wishes to register for one of these courses. The course may be taken for any number of units up to 12, depending upon the amount of work to be done.

85-509 Research in Psychology Practicum

Fall and Spring: 1 unit
All students registered for research units via 85-198 or 85-507/508 * to register, in addition, for this 1 unit course. This course will meet every other week (online, at a time to be determined by survey). This course will provide students with an opportunity to frame their research experience in a broader professional and scholastic perspective, as well as an opportunity to get feedback on ongoing research experiences. Topics to be covered include professional development, protections for researchers and participants (including Title IX), problem solving, and communication. Students will complete short homework assignments in relation to each topic as a way of maintaining engagement with the course materials, as well as brief written assignments reflecting on their research experience. Students will be connected with resources like the Global Communications Center and the Career and Professional Development Center to help students contextualize their research experience in ways that contribute to their ongoing professional aspirations.

85-601 Senior Thesis

Fall
This course is intended for senior Psychology or Cognitive Science majors who wish to conduct a research project under the direction of a faculty advisor. The project topic is to be selected jointly by the student and the advisor. The project will culminate in a senior paper which will be presented to the Department Head at the end of Fall Semester. Prerequisite: Grade of B or better in a previous research course required to enter, grade of B or better in first semester of senior thesis course required to complete, and permission of instructor. A formal proposal is required in the first semester. This course differs from the Honors Thesis sequence (66-501,502) in that it does not require Honors standing in HSS (i.e., there are no QPA requirements). This course differs from Research in Psychology (85-507,508) in that the student's original contribution to the research is expected to be more substantial, and in that a final written report of the project is to be presented to the Department.

85-602 Senior Thesis

Spring
This course is intended for senior Psychology or Cognitive Science majors who wish to conduct a research project under the direction of a faculty advisor. The project topic is to be selected jointly by the student and the advisor. The project will culminate in a senior paper which will be presented to the Department Head at the end of Fall Semester. Prerequisite: Grade of B or better in a previous research course required to enter, grade of B or better in first semester of senior thesis course required to complete, and permission of instructor. A formal proposal is required in the first semester. This course differs from the Honors Thesis sequence (66-501,602) in that it does not require Honors standing in HSS (i.e., there are no QPA requirements). This course differs from Research in Psychology (85-507,508) in that the student's original contribution to the research is expected to be more substantial, and in that a final written report of the project is to be presented to the Department.

85-730 Analytic Research Methods

Intermittent: 12 units
This class will teach students how to apply six major non-experimental research methods used in analytic behavioral analysis. Protocol Analysis. This method is used to study patterns and changes in problem-solving and their matches to theoretical models, including computational models. Corpus Analysis. This method is used to isolate patterns of behavioral and communication usage and change, as revealed through the study of the world-wide web and large computerized databases such as CHILDES, TalkBank, or the British National Corpus. Tools here include text searches and data-mining. Conversation Analysis. This is a microanalytic method used to examine sequencing, repair, and orientation in closely transcribed recordings of spoken interactions, as made available through systems such as the CABank database, as well as recorded programs on YouTube and elsewhere. Coding Systems. This approach seeks to capture interactional and behavioral structures in writing, teaching, interview, and other interactions. Here, there will be a special emphasis on the coding of instructional interactions. Gesture Analysis. This microanalytic method seeks to track patterns in gestural and nonverbal communication, often in association with spoken messages. Profile Analysis. This approach studies differences across learners at various ages and ability levels and group differences involving aphasia, autism, stuttering, dementia, and other individual differences. Students will work with data already available from previous studies, and will also learn to collect their own new datasets. Although the data being examined have been generated through naturalistic processes, they can be analyzed quantitatively using time-series analyses, non-parametric statistics, error matrices, and neural network simulations. In these various analyses, we will also consider how behavioral patterns are shape

85-747 Stress and Health Across Lifecourse

Intermittent
This seminar is designed to delve deeper into the topic of stress and health with a life course perspective. The aims of this course is to help students develop the conceptual and methodological skills necessary for interpreting empirical studies (as well as claims in pop culture) in this area of research and to understand the critical roles of time and timing. To facilitate these goals, the course will combine brief lectures, discussion of readings, oral presentations, and writing.

85-753 Mindfulness: Science and Practice

Intermittent
This course will focus on blending first-person experience with mindfulness practices (including mindfulness meditation) and learning about the scientific research on mindfulness. Students will engage in guided mindfulness exercises, develop a daily mindfulness practice, and try out different mindfulness training traditions. In addition, much of this course will be focused on applying a critical eye to the theory, measures, mechanisms, and effects of mindfulness (and mindfulness training interventions) across multiple domains cognition, social processes, behavior, biological mechanisms, and health. As such, this will be a small seminar course focused developing first-person experiences of mindfulness and on discussing the debates and opportunities related to the emerging science of mindfulness.

85-762 Seminar on Addiction

Fall: 9 units
This seminar will explore various topics central to the study of drug addiction, with a primary emphasis on psychological and neurobiological theories of drug addiction. We will also discuss research and clinical techniques related to the assessment, diagnosis, and treatment of substance use disorders and related problems. Emphasis will be on alcohol and tobacco, but other drugs will be discussed as well. The main course objective is to provide a unifying model for understanding the fundamental aspects of addiction.

85-765 Cognitive Neuroscience

Intermittent: 9 units
This course will cover fundamental findings and approaches in cognitive neuroscience, with the goal of providing an overview of the field at an advanced level. Topics will include high-level vison, spatial cognition, working memory, long-term memory, learning, language, executive control, and emotion. Each topic will be approached from a variety of methodological directions, for example, computational modeling, cognitive assessment in brain-damaged humans, non-invasive brain monitoring in humans, and single-neuron recording in animals. Lectures will alternate with sessions in seminar format. Prerequisites: Graduate standing or two upper-level psychology courses from the areas of developmental psychology, cognitive psychology, computational modeling of intelligence, neuropsychology or neuroscience.

85-793 Memory: Models & Mechanisms

Intermittent
This course will provide a basic understanding of human memory, covering both the many phenomena that have been studied over the years and also how theories have placed these phenomena within a general human cognitive system. The course will treat data and theory as equally important. Theory without empirical evidence is vacuous. Data without an explanatory mechanism is also unsatisfying. The course will cover many of the major principles of human memory starting with how information from the environment is encoded, processed and stored in memory. We will focus on how working memory (think of it as the Human CPU) affects how we encode and retrieve information from memory and what the limits are on this processing machinery. Theories of learning and the mechanisms involved in acquiring information as well as theories of forgetting will be examined in depth, along with variables that affect ease of encoding and obstacles to retrieval. The course will also focus on illusions of memory, how and why human memory is vulnerable to illusions and produces memory distortions. Most phenomena will be discussed in the context of theoretical explanations. Students will also learn about modeling approaches and how the various phenomena have been understood with different theoretical accounts. As a final project each student will develop a model to account for a phenomenon. This will either be fit to an existing body of data, or will take an existing theory, generate a new prediction based on that theory, and design an experiment to test whether the theory is supported or not (the experiment will not be run, but the design and predictions should be clear enough that it could be).

85-851 Personality and Health

Intermittent
The general purpose of this course is to examine possible connections between personality and physical well-being. Material will be presented at the outset of the semester that is designed to enable students to understand more fully how psychologists think about the concept of personality (what it is and what it does for us), how it is assessed, and how personality and health psychologists do research on the topic. As the semester progresses, we will explore and discuss research that links certain aspects of personality to health, illness, and mortality. The list of personality characteristics to be considered includes (but is not necessarily limited to) optimism/pessimism, conscientiousness, hostility, trait positive and negative affect, life purpose, and chronic goal adjustment strategies. As time permits, select person variables will also be considered, e.g., the impact of depressive mood on health. Class time will be largely taken by discussion of original research papers. Different sets of students will be responsible for leading these discussions. Grades will be based on a combination of class participation, quality of paper presentations, and performance on a final research paper.

Department of Social and Decision Sciences

Location: Porter Hall 208
www.cmu.edu/dietrich/sds (http://www.cmu.edu/dietrich/sds/)

The Department of Social and Decision Sciences is a multidisciplinary department that offers undergraduate programs that focus on decision making using a broad set of social science approaches. Theoretical and empirical work is seamlessly combined with the practical skills needed to excel in key decision making roles in the public, private, and non-profit sectors and in advanced graduate studies. Our students learn how to combine standards of rationality with the realities of human and organizational behavior and to apply these lessons across a wide variety of endeavors, ranging from government service to leadership positions consulting, marketing, data science, and other sectors.

The department offers undergraduate majors in Behavioral Economics, in Decision Science, and in Policy and Management. Each major includes a distinct set of required and elective courses. Course offerings leverage faculty strength in behavioral decision making, behavioral economics, and behavioral science approaches to public policy to produce a unique curriculum.

Our faculty is committed to the academic success and growth of our students and many of our undergraduates work with faculty on research projects and internships. The directors of the majors are easily accessible and encourage students to talk with them about their curriculum, progress, and available opportunities. Our academic advisors are committed to working with each individual student to help them create, clarify, and meet their goals.

The Department of Social and Decision Sciences has long been recognized as a global nexus of decision science expertise, offering undergraduate programs that are available at few other universities. Our cohesive majors combine theory and practice allowing our graduates to excel in a range of professions or in the pursuit of advanced studies.

The Major in Behavioral Economics

Peter Schwardmann, *Faculty Director*
Location: Porter Hall 319F
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The field of Behavioral Economics (BE) integrates perspectives from Economics and Psychology to better understand how people make consequential decisions and to leverage this understanding to improve the design of the policies, programs, and institutions that govern such behavior. The last decade has witnessed an explosion of interest in BE among governments and organizations, around the world, including here in the United States. On the policy front, this has led to the formation of government “nudge” units charged with applying BE principles to policy areas such as education, criminal justice, taxation, social benefit programs, consumer protection, and unemployment. Organizations have also aggressively sought to apply BE to encourage employee productivity, improve employee health and financial wellness, reshape managerial and hiring decisions, and to better understand and engage consumers.

The faculty in the Department of Social and Decision Sciences (SDS) has long stood at the forefront of research and teaching in BE. Our faculty has developed a reputation for working closely with governments and firms to help apply BE to address a range of issues such as predatory lending and consumer protection, bias among institutional investors, employee reward and incentive programs, behavioral barriers to retirement savings, participation in social service programs, medical adherence, pre-trial detainment of defendants, and gender and racial inequality in the workplace.

The new major of BE-- the first of its kind among US undergraduate institutions--was designed to rigorously train students in the field of Behavioral Economics and to encourage them to critically consider its relevance to policy and organizations. The major emphasizes both theory and the practical promise of BE to solve problems of importance to policy makers and organizations through the largest undergraduate selection of BE courses of any university in the world. Towards this end, students will learn to collect original data, design field and laboratory experiments, analyze data and draw causal inferences, and develop interventions to improve economic outcomes and decisions. The core requirements include courses in Economics, Psychology, Behavioral Economics, and quantitative methods- including experimental design and econometrics. Students who complete the major will be well positioned to enter the private sector in a role involving data or people analytics, marketing, corporate strategy, or human resources, to enter the public sector, or to enter a wide range of graduate degree programs.

Prerequisites

All Behavioral Economics majors must complete mathematics and statistics prerequisites (see below), by the end of the sophomore year.

Mathematics Prerequisite		Units
21-111-21-112	Calculus I-II	10-20
or 21-120	Differential and Integral Calculus	

Statistics Prerequisite		Units
36-200	Reasoning with Data	9

Curriculum

The core curriculum in Behavioral Economics consists of three Behavioral Economics courses, two Economic courses, two Psychology courses, three quantitative courses, and one project course.

Behavioral Economics Courses		Units
88-360	Behavioral Economics	9
88-365	Behavioral Economics and Public Policy	9
88-367	Behavioral Economics & Field Experiments in Organizations	9
		27

Economics Courses		Units
73-102	Principles of Microeconomics	9
or 73-104	Principles of Microeconomics Accelerated	
Second-Level Economics Course*		
88-221	Markets, Democracy, and Public Policy	9
or 73-103	Principles of Macroeconomics	
or 73-155	Models, Math, and Markets	
or 73-230	Intermediate Microeconomics	
or 73-328	Health Economics	
or 73-347	Game Theory Applications for Economics and Business	
or 73-359	Benefit-Cost Analysis	
or 73-408	Law and Economics	
or 73-421	Emerging Markets	
or 73-427	Sustainability, Energy, and Environmental Economics	
		18

* Second-Level Economics course CANNOT double count with the Economics Elective course.

Psychology Courses*		Units
88-120	Reason, Passion and Cognition **	9
88-130	Behavioral Economics for Life	9
or 88-302	Behavioral Decision Making	
		18

* Students can elect to take ***88-120 Reason, Passion and Cognition*** & ***88-130 Behavioral Economics for Life*** OR ***88-120 Reason, Passion and Cognition*** & ***88-302 Behavioral Decision Making***.
PLEASE NOTE: Students who have completed ***88-302 Behavioral Decision Making*** OR ***88-360 Behavioral Economics*** cannot take ***88-130 Behavioral Economics for Life***.

** 88-120 Should be taken in the first or sophomore year.

Quantitative Methods Courses		Units
36-202	Methods for Statistics & Data Science	9
88-251	Empirical Research Methods	9
88-252	Causal Inference: from Data to Decisions	9
or 73-274	Econometrics I	
		27

Senior Project Course		Units
88-453	Behavioral Economics Capstone	9
		9

ELECTIVES **36 units**

Complete at least 27 units from the following categories. Students MUST take one elective from the Economics category, and another from the Behavioral Economics category. The third elective may be chosen from either the Behavioral Economics or Psychology categories. Note that not all elective courses are offered every year.

Economics*		Units
88-323	Policy in a Global Economy	9
73-103	Principles of Macroeconomics	9
73-155	Models, Math, and Markets	9
73-230	Intermediate Microeconomics **	9
73-328	Health Economics	12
73-347	Game Theory Applications for Economics and Business	9
73-359	Benefit-Cost Analysis	9
73-408	Law and Economics	9
73-421	Emerging Markets ***	9
73-427	Sustainability, Energy, and Environmental Economics	9

* ANY 73-3XX or 73-4XX courses be counted as an economic elective course. Consult the Academic Advisor for more information about this process. NOTE: The Economics Elective course CANNOT double count with the Second-Level Economics core requirement.
** Requires additional Math beyond 21-112 or 21-120.
*** 73-421 has a required prerequisite of 73-103 Principles of Macroeconomics, which is NOT a course requirement for the BE major.

Behavioral Economics		Units
88-234	Negotiation: International Focus	9
88-235	Negotiation: Strategies and Behavioral Insights	9
88-255	Strategic Decision Making	9
88-261	Health Policy and Decision Making	9
88-275	Bubbles: Data Science for Human Minds	9
88-300	Programming and Data Analysis for Social Scientists	9
88-366	Behavioral Economics of Poverty and Development	9

Psychology		Units
88-230	Human Intelligence and Human Stupidity	9
88-231	Thinking in Person vs. Thinking Online	9
88-285	Deconstructing and Dismantling Discrimination	9
88-290	Confessions, Lies, and Gossip	9
88-344	Systems Analysis: Environmental Policy	9
88-312	Decision Models and Games	9
70-311	Organizational Behavior	9
70-385	Consumer Behavior *	9
70-443	Digital Marketing and Social Media Strategy	9
85-350	Psychology of Prejudice	9
85-358	Pro-Social Behavior	9
85-375	Crosscultural Psychology	9
85-377	Attitudes and Persuasion	9
85-442	Health Psychology	9
85-446	Psychology of Gender	9

* 70-385 has a required prerequisite of 70-381 Marketing 1, which is NOT a course requirement for the BE major.

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Note: Some courses have additional prerequisites.
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Behavioral Economics, B.S. Sample Curriculum

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
88-120 Reason, Passion and Cognition*	36-202 Methods for Statistics & Data Science	88-251 Empirical Research Methods	88-252 Causal Inference: from Data to Decisions
21-120 Differential and Integral Calculus	Second-Level Economics Course Pick One (88-221, 73-103, 73-155, 73-230 (requires Math beyond 21-112/21-120), 73-328, 73-347, 73-359, 73-408, 73-421, 73-427)	88-360 Behavioral Economics	88-302 Behavioral Decision Making
36-200 Reasoning with Data	Pick One (Grand Challenge Seminar, First Year Writing, Disciplinary Perspectives: Humanities)	88-365 Behavioral Economics and Public Policy	88-367 Behavioral Economics & Field Experiments in Organizations
73-102 Principles of Microeconomics Or 73-104 Principles of Microeconomics Accelerated	Pick One (Grand Challenge Seminar, First Year Writing, Disciplinary Perspectives: Humanities)	Gen Ed or Elective	Behavioral Economics Elective
Pick One (Grand Challenge Seminar, First Year Writing, Disciplinary Perspectives: Humanities)	Gen Ed or Elective	Gen Ed or Elective	Gen Ed or Elective

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
Economics Elective	Behavioral Economics or Psychology Elective	88-453 Behavioral Economics Capstone	Elective or Senior Honors Thesis**
Gen Ed or Elective	Gen Ed or Elective	Elective	Elective
Gen Ed or Elective	Elective	Elective	Elective
Elective	Elective	Elective	Elective
Elective	Elective	Elective	Elective

* Should be taken as the first course in Behavioral Economics major sequence. It is intended for students in their first or second year. It may be taken as late as the junior year.
** Senior Honors Thesis may be substituted in the Spring term for 88-453 Behavioral Economics Capstone, which is only offered in the Fall term.

This is presented as a recommended plan for completing major requirements. The major can be completed in as few as two years (not that it must be), but students may not have time for other opportunities such as additional majors or study abroad. Students may declare their major as early as the third week of the spring semester in the first-year. Students who are planning to attend the Washington Semester Program, to study abroad, to apply for the Heinz Accelerated Masters Program, or to pursue an additional major/minor may have a very different curriculum map and should consult early – and often – with the Behavioral Economics Academic Advisor.

Additional Major

Students who elect Behavioral Economics as an additional major must fulfill all of the requirements of the Behavioral Economics major.

Additional majors cannot count BE electives toward simultaneously fulfilling requirements for another major or minor. Students who are interested in an additional major in Behavioral Economics should consult the Behavioral Economics Academic Advisor for guidance.

Students pursuing Decision Science with an additional major in Behavioral Economics may only count 36-202 , 73-102, 88-120, 88-251 and 88-302 toward the completion of both majors.

Students pursuing Policy and Management with an additional major in Behavioral Economics may only count 36-202, 73-102 and 88-251 toward the completion of both majors.

The Major in Decision Science

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The interdisciplinary field of Decision Science seeks to understand and improve the judgment and decision making of individuals, groups, and organizations. Qualified graduates can continue to PhD programs in Decision Science or related fields (e.g., psychology, business), pursue professional degrees (e.g., MBA, MD, JD, MPH), or take professional positions in business, government, consulting, or the non-profit sector. Students work with faculty and the Academic Advisor to tailor their education to their personal needs and interest.

Carnegie Mellon is one of the leading centers for the study of Decision Science - and offers the only undergraduate major that integrates analytical and behavioral approaches to decision making. Our faculty are involved in applying Decision Science in a wide variety of areas, allowing them to share practical experiences with students. These applications include use of decision aids (e.g., effects on cognitive processes of using technology), medical decision making (e.g., harnessing decision principles to design interventions to promote healthy behavior), risk management (e.g., assessing and communicating the risks of climate change), marketing (e.g., understanding the effects of inter-temporal choice on purchasing decisions), and business (e.g., identifying unrecognized conflicts of interest).

Decision Science is grounded in theories and methods drawn from psychology, economics, philosophy, statistics, and management science. Courses in the major cover the three aspects of decision science: (a) normative analysis, creating formal models of choice; (b) descriptive research, studying how cognitive, emotional, social, and institutional factors affect judgment and choice, and (c) prescriptive interventions, seeking to improve judgment and decision making. In addition to gaining a broad education in the principles of judgment and decision making, Decision Science majors gain broadly applicable skills in research design and analysis and in application of research findings to behavioral problems in consumer, organizational, and public policy arenas..

The core courses present fundamental theories and results from the study of decision making, along with their application to real-world problems. They introduce students to methods for collecting and analyzing behavioral data. For example, students learn to conduct surveys (e.g., uncovering consumer or managerial preferences), design experiments (e.g., evaluating theories, comparing ways of presenting information), and evaluate the effectiveness of interventions.

The elective courses provide students with additional knowledge in areas of decision making that meet their personal, intellectual, and career goals. These courses are organized into six clusters: biological and behavioral aspects of decision making, managerial and organizational aspects, philosophical and ethical perspectives, economic and statistical methods, public policy, and research methods. Students can concentrate in one area or spread their studies across them. In addition to coursework, the department offers research opportunities for interested and qualified students. Participating in research helps students to extend their mastery of decision science, discover whether a research career is right for them, and get to know faculty and graduate students better.

Prerequisites

All Decision Science majors must complete mathematics, statistics, and analytic methods prerequisites (see below), by the end of the sophomore year.

Mathematics Prerequisite		Units
21-111-21-112	Calculus I-II	10-20
or 21-120	Differential and Integral Calculus	

Statistics Prerequisite		Units
36-200	Reasoning with Data	9

Students must take one course from the following set (or an approved alternative). Students may not count a course used to fulfill the Mathematics Prerequisite as also filling the Analytic Methods Prerequisite. Students may not count a course used to fulfill the Analytic Methods Prerequisite as also filling a Decision Science elective.

Analytic Methods Prerequisite		Units
21-122	Integration and Approximation	10
or 21-256	Multivariate Analysis	
or 21-257	Models and Methods for Optimization	
or 36-309	Experimental Design for Behavioral & Social Sciences	
or 36-401	Modern Regression	
or 36-410	Introduction to Probability Modeling	
or 80-210	Logic and Proofs	
or 80-211	Logic and Mathematical Inquiry	
or 80-315	Logics for Knowledge and Belief	
or 88-252	Causal Inference: from Data to Decisions	
or 88-300	Programming and Data Analysis for Social Scientists	

Curriculum

The core curriculum in Decision Science consists of five courses providing the theoretical perspectives of Decision Science, two courses in research methods, and one capstone.

Theoretical Perspectives		Units
73-102	Principles of Microeconomics	9
or 73-104	Principles of Microeconomics Accelerated	
85-102	Introduction to Psychology	9
88-120	Reason, Passion and Cognition *	9
88-223	Decision Analysis	12
88-302	Behavioral Decision Making	9
		48

* 88-120 should be taken in the freshman or sophomore year.

Statistical Research Methods (select one course)*		Units
36-202	Methods for Statistics & Data Science	9
or 36-309	Experimental Design for Behavioral & Social Sciences	
or 85-309	Statistical Concepts and Methods for Behavioral and Social Science	
*** Be sure to consult with your Decision Science advisor to discuss which course will best fit your plans and goals.**		**9**

SDS Research Methods		Units
88-251	Empirical Research Methods	9
		9

Electives 45 units

Complete at least 45 units of courses from the following list. Note that additional courses (most typically 88xxx courses) are occasionally added. **For the most up to date list of approved electives (and additional information about the courses), see the SDS website (https://www.cmu.edu/dietrich/sds/undergraduate/).**

Although the Decision Science major doesn't explicitly require students to take a capstone course, students who want to have real-world, professional experience should register for 88-454 Decision Science Capstone (this will count as one of the electives).

At least three of these courses (27 units) must be Department of Social and Decision Sciences courses (88-xxx) from the approved list.

88-150	Managing Decisions	9
88-221	Markets, Democracy, and Public Policy	9
88-230	Human Intelligence and Human Stupidity	9
88-231	Thinking in Person vs. Thinking Online	9
88-234	Negotiation: International Focus	9
88-235	Negotiation: Strategies and Behavioral Insights	9

88-252	Causal Inference: from Data to Decisions *	9
88-261	Health Policy and Decision Making	9
88-262	Medical Decision Making	9
88-275	Bubbles: Data Science for Human Minds	9
88-285	Deconstructing and Dismantling Discrimination	9
88-290	Confessions, Lies, and Gossip	9
88-300	Programming and Data Analysis for Social Scientists	9
88-312	Decision Models and Games	9
88-342	The Neuroscience of Decision Making	9
88-344	Systems Analysis: Environmental Policy	9
88-360	Behavioral Economics	9
88-365	Behavioral Economics and Public Policy	9
88-366	Behavioral Economics of Poverty and Development	9
88-367	Behavioral Economics & Field Experiments in Organizations	9
88-372	Social and Emotional Brain	9
88-379	Data-Driven Decision Analysis	9
88-451	Policy Analysis Senior Project	12
88-452	Policy Analysis Senior Project	12
88-454	Decision Science Capstone	9
70-311	Organizational Behavior	9
70-332	Business, Society and Ethics	9
70-381	Marketing I	9
70-443	Digital Marketing and Social Media Strategy	9
70-460	Mathematical Models for Consulting	9
73-265	Economics and Data Science	9
80-221	Philosophy of Social Science	9
80-324	Philosophy of Economics	9
84-369	Decision Science for International Relations	9
85-375	Crosscultural Psychology	9
85-442	Health Psychology	9

Note: Some courses have additional prerequisites.

Decision Science, B.S. Sample Curriculum

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
88-120 Reason, Passion and Cognition *	36-202 Methods for Statistics & Data Science	85-102 Introduction to Psychology	88-223 Decision Analysis
36-200 Reasoning with Data	Pick One (Grand Challenge Seminar, FYW, Disciplinary Perspectives: Humanities)	88-251 Empirical Research Methods	88-302 Behavioral Decision Making
21-120 Differential and Integral Calculus (or 21-111, depending on placement)	Pick One (Grand Challenge Seminar, FYW, Disciplinary Perspectives: Humanities)	88-252 Causal Inference: from Data to Decisions or other Analytic Methods course	88-300 Programming and Data Analysis for Social Scientists or other Analytic Methods course
Pick One (Grand Challenge Seminar, FYW, Disciplinary Perspectives: Humanities)	Gen Ed or Elective	Gen Ed or Elective	Decision Science Elective
73-102 Principles of Microeconomics	Gen Ed or Elective	Gen Ed or Elective	Gen Ed or Elective
			Gen Ed or Elective

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
Decision Science Elective	Decision Science Elective	Senior Honors Thesis or Elective	Senior Honors Thesis or Elective
Gen Ed or Elective	Gen Ed or Elective	Capstone or Decision Science Elective	Decision Science Elective
Elective	Elective	Elective	Elective
Elective	Elective	Elective	Elective
Elective		Elective	Elective

* 88-120 should be taken as the first course in the Decision Science sequence. It is intended for students in their first or second year; it is offered in Fall and Spring semesters. It may be taken as late as the junior year.

This is presented as a recommended plan for completing major requirements. The major can be completed in as few as two years (not that it must be), but students may not have time for other opportunities such as additional majors or study abroad. Students may declare their major as early as the third week of the spring semester in the first year. Students who are planning to attend the Washington Semester Program, to study abroad, to apply for the Heinz Accelerated Masters Program, or to pursue an additional major/minor may have a very different curriculum map and should consult early – and often – with the Decision Science Academic Advisor.

Students are encouraged to consider the Washington Semester Program as part of their education. Suitable courses will be considered as fulfilling requirements of electives in the major. Please send the course syllabus, along with a note explaining how the course addresses fundamental aspects of decision science in one of the six elective categories.

Additional Major in Decision Science

Students who elect Decision Science as an additional major must fulfill all of the requirements of the Decision Science major.

Students pursuing Behavioral Economics with an additional major in Decision Science may only count 36-202, 73-102, 88-120, 88-251 and 88-302 toward the completion of both majors.

Students pursuing Policy and Management with an additional major in Decision Science and may only count 36-202, 73-102, 88-223, and 88-251 toward the completion of both majors.

Additional majors cannot count menu electives toward simultaneously fulfilling more than one major or minor. Students who are interested in an additional major in Decision Science should see the Academic Advisor of the Decision Science program.

The Major in Policy and Management

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Connie Angermeier, *Senior Academic Program Manager and Advisor*
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Schedule an appointment: https://go.oncehub.com/ConnieAngermeier (https://go.oncehub.com/ConnieAngermeier/)

The Policy and Management major prepares students for key decision-making and management roles in government, non-profit organizations, and business. The major emphasizes analytical approaches to decision making, practical management skills, and empirical techniques necessary for graduates to excel in the public and private sectors. The multidisciplinary curriculum merges frontier knowledge on the ideals of decision making, policy, and data analysis, as well as the realities of individual behavior within various institutional settings that must be confronted if high-quality outcomes are to be attained.

The major is comprised of three required core areas taken by all Policy and Management majors, a capstone course, plus one of four concentration areas to be chosen by the student.

The three core areas are as follows:

The *Policy Core* gives students applied economic training and policy analysis experience. Students will gain an analytical understanding of some of the biggest domestic and global economic policy challenges, and gain an appreciation of the economic analysis of complex decisions, as well as the trade-off between economic and political-based decision making.

The *Management Core* focuses on real-world applications of decision making. Students will develop an understanding of effective negotiation strategies and tactics, and identify the barriers and the psychological factors that may prevent decision-makers from reaching wise agreements. The courses provide systematic methods for dealing with the complexities that make decisions difficult, ranging from incorporating issues of risk and uncertainty in decision making to dealing with choices that have mutually conflicting objectives. For example, a business or government agency may need to decide on a policy for mitigating the uncertain impacts of air pollution while simultaneously trying to minimize the costs of such a policy on manufacturing. A firm might want to consider the uncertain reductions in security dangers from alternative policies to protect against terrorism.

The *Empirical Core* focuses on key methods for collecting and analyzing data that are needed to make informed decisions. Students learn to use interviews, surveys, experiments, and econometric methods to enhance their ability to test existing, and design new, policies. Students will create statistical models to address questions asked in conceptual, computational, and data-driven investigations.

The required *Capstone* course gives students hands-on experience in a policy-related area. Students work in teams to apply the research and analytical methods learned in their other courses to a real-world problem.

Finally, the *four concentration areas* consist of four courses chosen by the student, in coordination with the Academic Advisor. The concentrations emphasize different aspects of decision making within the major:
(1) Analytics, (2) Policy, (3) Management, and (4) Law. Each of the concentration areas draws upon the research and teaching strength of the Department of Social and Decision Sciences. Additionally, select courses from other areas in the University have been identified and approved as fulfilling elective requirements within the concentrations. More detail will be found in the concentration areas below.

The Policy and Management major provides an excellent combination of theoretical and practical skills for students who intend to seek managerial positions. Because of its strong analytic orientation, it is also an excellent major for those who intend to go on to professional school programs in law, business, or public policy. It is also an appropriate choice for students pursuing graduate degrees in economics, political science, or decision science. One such graduate option is the accelerated master's program offered by the H. J. Heinz III School of Public Policy and Management, in which a student earns both a B.S. in Policy and Management and a M.S. in Public Policy and Management in five years.

Prerequisites

All Policy and Management majors must complete mathematics and statistics prerequisites (see below), by the end of the sophomore year.

Mathematics Prerequisite		Units
21-111-21-112	Calculus I-II	10-20
or 21-120	Differential and Integral Calculus	

Statistics Prerequisite		Units
36-200	Reasoning with Data	9

Curriculum

Policy Core		Units
73-102	Principles of Microeconomics	9
or 73-104	Principles of Microeconomics Accelerated	
88-221	Markets, Democracy, and Public Policy	9
		18

Management Core		Units
88-150	Managing Decisions	9
or 88-255	Strategic Decision Making	
88-223	Decision Analysis	12
88-235	Negotiation: Strategies and Behavioral Insights	9
or 88-234	Negotiation: International Focus	
		30

Empirical Core		Units
36-202	Methods for Statistics & Data Science	9
88-251	Empirical Research Methods	9
88-252	Causal Inference: from Data to Decisions	9
or 88-275	Bubbles: Data Science for Human Minds	
		27

Capstone		
88-451	Policy Analysis Senior Project	12
or 88-452	Policy Analysis Senior Project	
(88452 is offered in fall, 88451 in spring)		

Concentration 36 units

Complete at least 36 units (a minimum of four courses) from the following concentrations of courses. Students are required to declare a concentration before their graduating semester, but are not required to choose a concentration when they initially declare (typically in the freshman or sophomore year). In fact, students are encouraged to take many of the core classes before making their concentration selection so that they can make a well-informed decision.

1. Analytics Concentration (minimum four total courses)		Units
Programming (one course)		**9**
88-300	Programming and Data Analysis for Social Scientists	9
Analytics/Empirical electives (select any two courses)		**18**
88-252	Causal Inference: from Data to Decisions (if not taken in Empirical Core)	9
88-275	Bubbles: Data Science for Human Minds (if not taken in Empirical Core)	9
88-312	Decision Models and Games	9
88-379	Data-Driven Decision Analysis	9
36-303	Sampling, Survey and Society	9
36-315	Statistical Graphics and Visualization	9
70-257	Optimization for Business	9
70-374	Data Mining & Business Analytics	9
70-455	Data Management Fundamentals	9
70-460	Mathematical Models for Consulting	9
90-834	Health Care Geographical Information Systems *	12
Analytics concentration breadth elective (select one course from any of the other three concentrations; must be 88xxx)		**9**

* other Heinz courses may also be approved. Please talk with the P&M advisor for information about getting approval for Heinz course registration.

2. Policy Concentration (minimum four total courses)		Units
Policy electives (select three courses; at least one of the three must be 88xxx)		**27**
88-230	Human Intelligence and Human Stupidity	9
88-261	Health Policy and Decision Making	9
88-285	Deconstructing and Dismantling Discrimination	9
88-323	Policy in a Global Economy	9
88-344	Systems Analysis: Environmental Policy	9
88-365	Behavioral Economics and Public Policy	9
88-366	Behavioral Economics of Poverty and Development	9
88-367	Behavioral Economics & Field Experiments in Organizations	9
88-411	Rise of the Asian Economies	9
36-303	Sampling, Survey and Society	9
73-328	Health Economics	12
80-244	Environmental Ethics	9
84-362	Diplomacy and Statecraft	9
84-389	Terrorism and Insurgency	9
90-443	Urban and Regional Economic Development *	12
Policy concentration breadth elective (select one course from any of the other three concentrations; must be 88xxx)		**9**

* other Heinz courses may also be approved. Please talk with the P&M advisor for information about getting approval for Heinz course registration.

3. Management Concentration (minimum four total courses)		Units
Management electives (select three courses; at least one of the three must be 88xxx)		**27**
88-231	Thinking in Person vs. Thinking Online	9
88-234	Negotiation: International Focus (if not taken in Management Core)	9
88-235	Negotiation: Strategies and Behavioral Insights (if not taken in Management Core)	9
88-341	Team Dynamics and Leadership	9
88-411	Rise of the Asian Economies	9
70-311	Organizational Behavior	9
70-332	Business, Society and Ethics	9
70-342	Managing Across Cultures	9
70-371	Operations Management	9
70-381	Marketing I	9
70-430	International Management	9
94-408	Management Consulting	12
94-423	Measuring Social *	12
Management concentration breadth elective (select one course from any of the other three concentrations; must be 88xxx)		**9**

* other Heinz courses may also be approved. Please talk with the P&M advisor for information about getting approval for Heinz course registration.

4. Law Concentration (minimum four total courses)		Units
Topics of Law (select one course)		**9**
88-281	Topics in Law: 1st Amendment	9
88-284	Topics of Law: The Bill of Rights	9
Law electives (select any two courses)		**18**
88-281	Topics in Law: 1st Amendment (if not used in required)	9
88-284	Topics of Law: The Bill of Rights (if not used in required)	9
70-364	Business Law	6
70-365	International Trade and International Law	9
73-408	Law and Economics	9
76-219	Law & Blame	9
76-450	Law, Culture, and the Humanities	9
76-475	Law, Performance, and Identity	9
79-360	Crime, Policing, and the Law: Historical and Contemporary Perspectives	9
80-447	Global Justice	9
84-373	Emerging Technologies and International Law	9
Law concentration breadth elective (select one course from any of the other three concentrations; must be 88xxx)		**9**

NOTE: Some courses have additional prerequisites.

Policy and Management, B.S. Sample Curriculum

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
88-150 Managing Decisions or 88-255 in spring	88-255 Strategic Decision Making or 88-150 in fall	88-235 Negotiation: Strategies and Behavioral Insights or 88-234 in spring	88-221 Markets, Democracy, and Public Policy
36-200 Reasoning with Data	36-202 Methods for Statistics & Data Science	88-251 Empirical Research Methods	88-223 Decision Analysis
21-120 Differential and Integral Calculus (or 21-111, depending on placement)	73-102 Principles of Microeconomics	88-252 Causal Inference: from Data to Decisions or 88-275 in spring	88-234 Negotiation: International Focus or 88-235 in fall
Pick One (Grand Challenge Seminar, FYW, Disciplinary Perspectives: Humanities)	Pick One (Grand Challenge Seminar, FYW, Disciplinary Perspectives: Humanities)	Gen Ed or Elective	88-275 Bubbles: Data Science for Human Minds or 88-252 in fall
Gen Ed or Elective	Pick One (Grand Challenge Seminar, FYW, Disciplinary Perspectives: Humanities)	Gen Ed or Elective	Gen Ed or Elective

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
Policy & Management concentration elective	Policy & Management concentration elective	88-452 Policy Analysis Senior Project or 88-451 in spring	88-451 Policy Analysis Senior Project or 88-452 in fall
Policy & Management concentration elective	Policy & Management concentration elective	Senior Honors Thesis or Elective	Senior Honors Thesis or Elective
Gen Ed	Elective	Complete remaining gen eds/electives	Complete remaining gen eds/electives
Elective	Elective	additional Policy & Management concentration electives	additional Policy & Management concentration electives
Elective	Elective	additional Policy & Management concentration electives	additional Policy & Management concentration electives
Students may consider the CMU Washington Semester Program or study abroad in this semester	Students may consider the CMU Washington Semester Program or study abroad in this semester		

This is presented as a recommended plan for completing major requirements. Students may declare their major as early as the third week of the spring semester in the first year. Students who are planning to attend the Washington Semester Program, to study abroad, to apply for the Heinz Accelerated Masters Program, or to pursue an additional major/minor may have a very different curriculum map and should consult early – and often – with the Policy and Management Academic Advisor.

Students are encouraged to consider the Washington Semester Program as part of their education. Suitable courses may be considered as fulfilling requirements of concentration electives in the major. Please discuss course selections with the Academic Advisor during the application phase to the program.

Additional Major

Students who elect Policy and Management as an additional major must fulfill all of the requirements of the Policy and Management major. For additional majors in Policy and Management, courses taken as concentration electives may not count toward the student's primary major or other program.

Students pursuing Behavioral Economics, Policy, and Organizations with an additional major in Policy and Management may only count 36-202 , 73-102, and 88-251 (and 88-252, if taken in Empirical Core) toward the completion of both majors.

Students pursuing Decision Science with an additional major in Policy and Management may only count 36-202 , 73-102, 88-223 , and 88-251 toward the completion of both majors.

Additional majors cannot count menu electives toward simultaneously fulfilling more than one major or minor. Students who are interested in an additional major in Policy and Management should see the Academic Advisor of the Policy and Management program.

The Minor in Behavioral Economics

Peter Schwardmann, *Faculty Director*
Location: Porter Hall 319F
schwardmann (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/departmentofsocialanddecisionsciences/schwardmann@cmu.edu)@andrew.cmu.edu (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/departmentofsocialanddecisionsciences/schwardmann@cmu.edu)

Lizzy Stoyle, *Senior Academic Advisor*
Location: 208G
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The minor in Behavioral Economics, provides students with a selective survey of disciplinary perspectives. The field of Behavioral Economics (BE) integrates perspectives from Economics and Psychology to better understand how people make consequential decisions and to leverage this understanding to improve the design of the policies, programs, and institutions that govern such behavior. The core requirements include courses in Economics, Psychology, Behavioral Economics, and quantitative methods- including experimental design and econometrics. Students who elect Behavioral Economics as a minor must complete the six core courses and one elective from the elective set (below).

Students may double-count two courses with another major or minor. 73-102 is excluded from this double count policy. The prerequisite course of 36-200 (or its equivalent) is also excluded.

Curriculum

The core curriculum in Behavioral Economics consists of one quantitative course, two Economic courses, one Psychology course, and two Behavioral Economics courses.

CURRICULUM 63

Core Courses 54

Quantitative Methods Core		Units
36-202	Methods for Statistics & Data Science	9

Economics Core		Units
73-102	Principles of Microeconomics	9

or 73-104	Principles of Microeconomics Accelerated	
Second-Level Economics Course		
88-221	Markets, Democracy, and Public Policy	9
or 73-103	Principles of Macroeconomics	
or 73-155	Models, Math, and Markets	
or 73-230	Intermediate Microeconomics	
or 73-328	Health Economics	
or 73-347	Game Theory Applications for Economics and Business	
or 73-359	Benefit-Cost Analysis	
or 73-408	Law and Economics	
or 73-421	Emerging Markets	
or 73-427	Sustainability, Energy, and Environmental Economics	
		18

Psychology Core		Units
88-120	Reason, Passion and Cognition	9

Behavioral Economics Core		Units
88-360	Behavioral Economics	9
88-367	Behavioral Economics & Field Experiments in Organizations *	9
or 88-365	Behavioral Economics and Public Policy	
		18

* Behavioral Economics core courses CANNOT double count with the elective course.

Elective Courses 9

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Complete at least one of the courses (9 units) from the following
 list. Note: Behavioral Economics core courses CANNOT double count
 with the elective course.
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Elective Courses		Units
88-130	Behavioral Economics for Life *	9
88-221	Markets, Democracy, and Public Policy	9
88-230	Human Intelligence and Human Stupidity	9
88-231	Thinking in Person vs. Thinking Online	9
88-234	Negotiation: International Focus	9
88-235	Negotiation: Strategies and Behavioral Insights	9
88-251	Empirical Research Methods	9
88-252	Causal Inference: from Data to Decisions	9
88-255	Strategic Decision Making	9
88-261	Health Policy and Decision Making	9
88-275	Bubbles: Data Science for Human Minds	9
88-285	Deconstructing and Dismantling Discrimination	9
88-290	Confessions, Lies, and Gossip	9
88-300	Programming and Data Analysis for Social Scientists	9
88-302	Behavioral Decision Making	9
88-312	Decision Models and Games	9
88-323	Policy in a Global Economy	9
88-344	Systems Analysis: Environmental Policy	9
88-365	Behavioral Economics and Public Policy	9
88-366	Behavioral Economics of Poverty and Development	9
88-367	Behavioral Economics & Field Experiments in Organizations	9

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Note: Some courses have additional prerequisites.
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* __PLEASE NOTE:__ Students who have completed ***88-302 Behavioral Decision Making*** OR ***88-360 Behavioral Economics*** cannot take ***88-130 Behavioral Economics for Life***.

The Minor in Decision Science

Peter Schwardmann, *Faculty Director*
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Connie Angermeier, *Senior Academic Program Manager*
Advises Additional Majors and Minors in Decision Science
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The minor in Decision Science provides students with a selective survey of disciplinary perspectives. The courses present descriptive and normative approaches to judgment and decision making, as well as some application of theories and results to real-world problems. Students who elect Decision Science as a minor must complete the four core courses (below) and two electives from the elective set (below).

Students may double-count two courses with another major or minor.

Curriculum 57 units

Core Courses 39 units

73-102	Principles of Microeconomics	9
or 73-104	Principles of Microeconomics Accelerated	
88-120	Reason, Passion and Cognition	9
88-223	Decision Analysis	12
88-302	Behavioral Decision Making	9

Elective Courses 18 units

Complete two courses from the following list. At least one of the courses (9 units) must be a Social and Decision Sciences course (88-xxx) from the approved list. Note that additional courses (most typically 88xxx courses) are occasionally added. For the most up to date list of approved electives (and additional information about the courses), see the SDS website (https://www.cmu.edu/dietrich/sds/undergraduate/).

88-150	Managing Decisions	9
88-221	Markets, Democracy, and Public Policy	9
88-230	Human Intelligence and Human Stupidity	9
88-231	Thinking in Person vs. Thinking Online	9
88-234	Negotiation: International Focus	9
88-235	Negotiation: Strategies and Behavioral Insights	9
88-252	Causal Inference: from Data to Decisions	9
88-255	Strategic Decision Making	9
88-261	Health Policy and Decision Making	9
88-262	Medical Decision Making	9
88-275	Bubbles: Data Science for Human Minds	9
88-285	Deconstructing and Dismantling Discrimination	9
88-290	Confessions, Lies, and Gossip	9
88-300	Programming and Data Analysis for Social Scientists	9
88-312	Decision Models and Games	9
88-342	The Neuroscience of Decision Making	9
88-344	Systems Analysis: Environmental Policy	9
88-360	Behavioral Economics	9
88-365	Behavioral Economics and Public Policy	9
88-366	Behavioral Economics of Poverty and Development	9
88-367	Behavioral Economics & Field Experiments in Organizations	9
88-372	Social and Emotional Brain	9
88-379	Data-Driven Decision Analysis	9
88-451	Policy Analysis Senior Project	12
88-452	Policy Analysis Senior Project	12
88-454	Decision Science Capstone	9
70-311	Organizational Behavior	9
70-332	Business, Society and Ethics	9
70-443	Digital Marketing and Social Media Strategy	9
70-460	Mathematical Models for Consulting	9
73-365	Firms, Market Structures, and Strategy	9
80-221	Philosophy of Social Science	9
80-324	Philosophy of Economics	9
84-369	Decision Science for International Relations	9
85-375	Crosscultural Psychology	9

Note: Some courses have additional prerequisites.

The Minor in Policy and Management

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Location: Porter Hall 208A
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Schedule an appointment: https://go.oncehub.com/ConnieAngermeier (https://go.oncehub.com/ConnieAngermeier/)

Regardless of major, many Carnegie Mellon graduates will face analytical and managerial challenges and responsibilities in their professional lives. Whether these are in their area of expertise or in more general settings, these roles will to some degree require assumption of the responsibility for directing the work of others. The Policy and Management minor is intended for students who expect to need these management concepts and skills.

Students may double-count one course with another major or minor.

Curriculum 57 units

Required Courses 39 units

73-102	Principles of Microeconomics	9
or 73-104	Principles of Microeconomics Accelerated	
88-150	Managing Decisions	9
or 88-255	Strategic Decision Making	
88-221	Markets, Democracy, and Public Policy	9
88-223	Decision Analysis	12

18 unitsElectives

Complete two courses (at least 18 units) from any of the concentrations (Analytics, Policy, Management, and Law). **Courses do not need to be taken from the same concentration.** The courses are listed by their concentration categories as a way to guide students. At least one of the courses (9 units) must be a Social and Decision Sciences course (88-xxx).

Analytics Concentration		
88-252	Causal Inference: from Data to Decisions	9
88-275	Bubbles: Data Science for Human Minds	9
88-300	Programming and Data Analysis for Social Scientists	9
88-312	Decision Models and Games	9
88-379	Data-Driven Decision Analysis	9
36-303	Sampling, Survey and Society	9
36-315	Statistical Graphics and Visualization	9
70-257	Optimization for Business	9
70-374	Data Mining & Business Analytics	9
70-455	Data Management Fundamentals	9
70-460	Mathematical Models for Consulting	9
90-834	Health Care Geographical Information Systems *	12

* other Heinz courses are also approved. Please talk with the P&M advisor for information about getting approval for Heinz course registration

Policy Concentration		Units
88-230	Human Intelligence and Human Stupidity	9
88-261	Health Policy and Decision Making	9
88-285	Deconstructing and Dismantling Discrimination	9
88-323	Policy in a Global Economy	9
88-344	Systems Analysis: Environmental Policy	9
88-365	Behavioral Economics and Public Policy	9
88-366	Behavioral Economics of Poverty and Development	9
88-367	Behavioral Economics & Field Experiments in Organizations	9
88-411	Rise of the Asian Economies	9
36-303	Sampling, Survey and Society	9
73-328	Health Economics	12
80-244	Environmental Ethics	9
84-362	Diplomacy and Statecraft	9
84-389	Terrorism and Insurgency	9
90-443	Urban and Regional Economic Development	12

* other Heinz courses are also approved. Please talk with the P&M advisor for information about getting approval for Heinz course registration

Management Concentration		Units
88-231	Thinking in Person vs. Thinking Online	9
88-234	Negotiation: International Focus	9
88-235	Negotiation: Strategies and Behavioral Insights	9
88-341	Team Dynamics and Leadership	9
88-411	Rise of the Asian Economies	9
70-311	Organizational Behavior	9
70-332	Business, Society and Ethics	9
70-342	Managing Across Cultures	9
70-371	Operations Management	9
70-381	Marketing I	9
70-430	International Management	9
94-423	Measuring Social	12

Law Concentration		Units
88-281	Topics in Law: 1st Amendment	9
88-284	Topics of Law: The Bill of Rights	9
70-364	Business Law	6
70-365	International Trade and International Law	9
73-408	Law and Economics	9
76-219	Law & Blame	9
76-450	Law, Culture, and the Humanities	9
76-475	Law, Performance, and Identity	9
79-360	Crime, Policing, and the Law: Historical and Contemporary Perspectives	9
80-447	Global Justice	9
84-373	Emerging Technologies and International Law	9

Faculty

GRETCHEN CHAPMAN , Professor of Psychology – Ph.D., University of Pennsylvania ; Carnegie Mellon, 2017–

ERIN CARBONE, Visiting Assistant Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2023–

JOHN CONLON, Assistant Professor – Ph.D., Harvard University; Carnegie Mellon, 2024–

SIMON DEDEO, Associate Professor of Social and Decision Sciences – Ph.D., Princeton University; Carnegie Mellon, 2017–

JULIE DOWNS, Professor of Psychology – Ph.D., Princeton University; Carnegie Mellon, 1995–

CHRISTINA FONG, Senior Research Scientist – Ph.D., University of Massachusetts, Amherst; Carnegie Mellon, 2001–

RUSSELL GOLMAN, Associate Professor of Behavioral Economics and Decision Science – Ph.D., The University of Michigan; Carnegie Mellon, 2010–

CLEOTILDE GONZALEZ, Research Professor of Information and Decision Sciences – Ph.D., Texas Tech University; Carnegie Mellon, 2000–

KEVIN JARBO, Assistant Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2021–

MARK S. KAMLET, University Professor of Economics and Public Policy and Provost Emeritus – Ph.D., University of California, Berkeley; Carnegie Mellon, 1978–

GEORGE F. LOEWENSTEIN, Herbert A. Simon University Professor of Economics and Psychology – Ph.D., Yale University; Carnegie Mellon, 1990–

JOHN H. MILLER, Professor of Economics and Social Science – Ph.D., The University of Michigan; Carnegie Mellon, 1989–

LINDA MOYA, Distinguished Service Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2016–

DANEIL OPPENHEIMER, Professor of Psychology – Ph.D., Stanford University; Carnegie Mellon, 2017–

MARK PATTERSON, Assistant Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2019–

SILVIA SACCARDO, Associate Professor of Economics – Ph.D., University of California, San Diego; Carnegie Mellon, 2016–

PETER SCHWARDMANN, Associate Professor of Economics – Ph.D., Toulouse School of Economics; Carnegie Mellon, 2021–

MANASVINI SINGH, Assistant Professor – Ph.D., Emory University; Carnegie Mellon, 2023–

Emeriti Faculty

LINDA BABCOCK, James Mellon Walton Professor of Economics – Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 1988–

PAUL S. FISCHBECK, Professor of Social and Decision Sciences and Engineering and Public Policy – Ph.D., Stanford University; Carnegie Mellon, 1990–

DAVID A. HOUNSHELL, David M. Roderick Professor of Technology and Social Change – Ph.D., University of Delaware; Carnegie Mellon, 1991–

Adjunct Faculty

MATTHEW MEHALIK, Adjunct Instructor – Ph.D., University of Virginia; Carnegie Mellon, 2008–

MARY JO MILLER – J.D., Duquesne University; Carnegie Mellon, 1999–

DAVID RODE, Adjunct Instructor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2022–

Department of Social and Decision Sciences Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

88-120 Reason, Passion and Cognition

Fall: 9 units
How do we make decisions? Reason, Passion, and Cognition will be an introduction to the psychology of preference, judgment, and choice. Why do people behave in ways that cannot be defended as "rational" - and how do these deviations inform us about the processes that the mind uses to make fast-and-frugal decisions? The course will focus on the ways that cognitive and emotional processes relate to decisions made in the laboratory and in everyday decision making and will be based on rigorous experimental research.

88-130 Behavioral Economics for Life

Fall: 9 units
Are we humans or econs? Econs are analytical, make rational judgments and decisions, are deliberate and patient, and are able to perfectly implement their plans. Humans, however, are influenced by emotions, have systematic biases in their judgment and decision-making, can be impulsive and lack self-control, and often struggle implementing their plans. College students (and professors) are humans and as such we sometimes procrastinate, eat poorly, don't get enough sleep, skip out on going to the gym, make money mistakes, feel lonely, misjudge others, inadvertently discriminate against others, engage in unnecessary conflict, and don't live up to our own ethical standards. This course teaches you the science of behavioral economics-how it developed and is evolving as a field and how it can help you to improve your life now during college and later in your professional life. You will learn about evidence-based behavioral strategies and how they can help you to be happier, healthier and wealthier. You will also have the opportunity to try some of these strategies yourself and reflect on whether to incorporate them into your daily routines.

88-140 Introduction to Sociology

Spring: 9 units
tba

88-150 Managing Decisions

Fall: 9 units
We make decisions constantly, but making good decisions is hard. Future employers will pay handsomely for decisions that are well thought out, defendable, and understandable. How do we decide how to decide? What is a "good" decision? This course will introduce normative decision-making concepts, including how to formulate decision problems and techniques that account for uncertainty and time preference. Students will learn how to place a quantitative value on information. The course will introduce key decision-making concepts using applications from fields such as decision sciences, business and economics, and public policy. Although prior knowledge of Microsoft Excel spreadsheets is not required, prior familiarity with Excel and a general level of numeracy will be useful.

88-198 Research Training: Social and Decision Sciences

Fall and Spring
This course is part of a set of 100-level courses offered by Dietrich departments as independent studies for second-semester freshmen, and first- or second-semester sophomores, in the College. In general, these courses are designed to give students some real research experience through work on a faculty project or lab in ways that might stimulate and nurture subsequent interest in research participation. Faculty and students devise a regular meeting and task schedule. Each Research Training course is worth 9 units, which generally means a minimum of about 9 work-hours per week. These courses are offered only as electives; i.e., they cannot be applied toward a college or major requirement, although the units do count toward graduation as elective units. Additional details (including a roster and descriptions of Research Training Courses available in any given semester) are available in the Dietrich Academic Advisory Center.

88-200 SDS Colloquium

Spring: 3 units
The SDS Colloquium is an opportunity for students to gather and discuss topics related to the various opportunities available both during the undergraduate career and after graduation. Students will explore areas such as academic planning, personal and professional values, and professional communication/communication skills. Co-curricular experiences such as: study abroad, research, internship/career planning and goal setting, and graduate school are among the topics to be presented. Students will have the opportunity to talk with SDS advisors, faculty, and alumni as well as with other professionals from around the University. Sophomore or junior standing is required.

88-221 Markets, Democracy, and Public Policy

Spring: 9 units
In this course, you will learn a powerful set of concepts for analyzing: (i) What markets are and the positive and negative effects they may have on individuals and society (ii) What democracy is, how markets and democracy may interact, and some ways in which democracy is vulnerable (iii) How public policy might soften some of the negative effects of markets and support democracy. You will learn theory via application to historical and current real-world examples. You will appreciate how theory illuminates the real-world examples.
Prerequisite: 73-102

88-223 Decision Analysis

Spring: 12 units
This course offers practical guidance about how to make better decisions and teaches students how to use modeling to do decision analysis. We analyze decisions involving uncertainty, risk, and time delay. In addition to methods of decision analysis, the course will also emphasize sensitivity analysis and communication of recommendations.
Prerequisites: 36-201 or 36-247 or 36-211 or 36-207 or 36-200 or 70-207 or 36-200 or 36-225 or 36-217

88-230 Human Intelligence and Human Stupidity

Fall: 9 units
By some standards, humans are an incredibly intelligent species. We have set foot on the moon, split the atom, and produced extraordinary works of art and literature (including the complete works of Shakespeare, which, despite theoretical accounts to the contrary, no amount of monkeys on typewriters has ever been able to duplicate). And yet. we are also the species that has brought about the Darwin Awards, spent $125 million sending a probe to Mars which was unable to function because engineers failed to convert inches to centimeters, and produced cringe-worthy works of art and literature (including the 1964 movie "Santa Claus Conquers the Martians" which no amount of monkeys on typewriters would ever want to duplicate.). What is intelligence and how does it vary across individuals and over our lifespans? What are we good at, and what are we bad at, and why? Are there things that that make us dumber? Are there things we can do to make ourselves smarter? How should what we know about the range of human intellectual abilities guide policy, education, law, medicine, and business; what implications does this have regarding the tasks/jobs that humans should be doing and the tasks/jobs that machines ought to do? Using cutting edge research from psychology and decision science, this course will explore the strange contradiction that defines the human experience: How are we simultaneously so smart and so dumb?

88-231 Thinking in Person vs. Thinking Online

Intermittent: 9 units
Being online changes how we think. Different media lead us to ask different questions, remember (or forget) different information, attend to different details, and interact with other people in different ways. These types of thinking aren't inherently better or worse, but they may be better or worse for facilitating specific goals. Too often, we use a particular medium/technology without considering how it will influence our thinking. This can lead us to be less efficient or less effective at a task than we otherwise might be, or can qualitatively change the nature of our outcomes. In this class, we will explore how the media we use affects the character of our thinking, so as to enable students to make mindful and deliberate choices about how to interact with media in ways that support the type of thinking desired and appropriate for their goals. Moreover, we will examine how to optimize media for specific goals in important applied domains, such as education, medicine, policy, child-rearing, and dating.

88-234 Negotiation: International Focus

Spring: 9 units
Most people think negotiation is all about strategies and tactics, that is what you do and say during a negotiation. However, negotiation is best understood by analyzing the contextual environment in which the negotiation takes place. This class focuses on negotiations that take place across international borders and examining how the features of the negotiation environment drive the negotiation process and ultimately the results. We will show how features such as the historical relationships between the parties, the constituents and political environment, the cultural norms, alternatives to a negotiated agreement, linkages to future negotiations with other countries, whether the negotiation takes place openly or behind closed doors, and the psychological process will influence the negotiating agents, process, and outcomes. Note that this framework can be applied to any negotiation situation to shed light on what transpired during a negotiation and how an agreement ultimately was or was not reached.

88-235 Negotiation: Strategies and Behavioral Insights

Fall: 9 units
Negotiation is a critical skill that is essential for success in today's world. Decision-makers use negotiation to reach agreements with co-workers, bosses, clients, service providers, subordinates, firms, family, roommates, and friends. Regardless of one's career path, learning how to negotiate effectively is important. This course provides a systematic and insightful approach to negotiation - the art and science of securing agreements between interdependent parties. Through experiential exercises, students will learn to analyze the features of the negotiation environment, develop an understanding of effective negotiation strategies and tactics, and identify the behavioral barriers and psychological factors that may prevent decision-makers from reaching wise agreements. The exercises, which feature negotiations in a variety of contexts including business negotiations, salary negotiations, interpersonal negotiations, and team negotiations, are designed to provide students with an opportunity to practice new strategies in a low-risk environment, receive feedback, and apply new knowledge to subsequent exercises. In-class discussions and lectures will complement the exercises, allowing students to explore and apply theoretical concepts to practical scenarios. This course is appropriate for students of any major who are interested in refining their negotiation skills.

88-251 Empirical Research Methods

Fall: 9 units
This course teaches students how to evaluate and conduct original research regarding human behavior, whether it be in economic, social, or political settings. The course gives students practical experience in many of the most commonly used research techniques, including surveys, experiments, and quasi-experimental analysis. Although the course focuses primarily on the relationship between formulating research questions and implementing the appropriate methods to answer them, students can expect regularly to apply the statistical techniques learned in the course prerequisites, including regression.
Prerequisites: 36-201 or 36-200 or 36-207 or 36-247

88-252 Causal Inference: from Data to Decisions

Spring: 9 units
Causal questions are pervasive in the social and behavioral sciences, and empirical researchers often use regression analysis as a tool for tackling such questions. This course focuses on the scientific problem of analyzing causal hypotheses in real-world settings, not on the mathematical details of regression. After clearly distinguishing prediction from causation, we discuss how to represent causal hypotheses and how to use regressions to analyze both predictive and causal hypotheses. Using in-class data exercises throughout, we will examine how to move from an interesting but somewhat vague question about the world (e.g., do police discriminate based on race and gender, do NFL athletes choke under high pressure, does parenthood improve happiness) to a clear statistical model that, when estimated, meaningfully addresses the question asked. The course emphasizes causal analysis as the main research goal and multivariate linear regression as the main statistical tool. After mastering basic techniques, we will introduce students to more advanced econometric approaches such as panel regressions and instrumental variables to deal with trickier settings in which causal inference is more challenging (e.g., do more guns lead to more violence?). In keeping with the hands-on philosophy of the course, a central focus of the semester will be a group research paper/presentation where students will have the opportunity to formulate and empirically test a research question of their choosing. Students will learn how to find, clean, and analyze a new dataset, and then concisely communicate their findings in the form of a scientific paper (and accompanying presentation). The research project makes this course excellent preparation for any student who hopes to ultimately write an undergraduate thesis.
Prerequisites: 85-309 or 70-208 or 36-309 or 36-202

88-255 Strategic Decision Making

Fall: 9 units
How do people navigate social interactions when their goals are in conflict? When should a person cooperate and when should a person pursue self-interest in an ongoing social interaction? How can a business establish strategic partnerships that create value and at the same time battle with competitors to take advantage of the value they create? Strategic decision making requires a framework to think through the implications of cooperation and of competition. This course gives you a systematic approach to understanding how people, firms, or countries interact with one another to achieve their own goals. We focus on the practical application of theory-based strategic principles and on their behavioral validity (whereas traditional game theory courses usually focus on formal modeling techniques). Readings will focus on real-life stories accompanied by a full analysis of the principles involved. The class will be organized as a seminar, centered around discussion, not lecture. Students will also be placed in the role of strategist in occasional simulations in class.

88-261 Health Policy and Decision Making

Fall: 9 units
Why does picking the right healthcare plan feel like a gamble-and how do you win? Why are two identical pills priced worlds apart? What guides a doctor's recommendation and #8212; science, or the invisible forces of economics and psychology? Why can't a tech-rich health system guarantee good health for all? Can a policy change really nudge a nation towards better health, or is that a fantasy? Join this course to tackle these puzzles, cutting through the complex maze of health decisions, cost disparities, and policy impacts (with a focus on the US). Debate, challenge, and uncover the forces molding healthcare. Ready for a deep dive into the mechanics of healthcare? This is your starting line.

88-262 Medical Decision Making

Spring: 9 units
tba

88-275 Bubbles: Data Science for Human Minds

Fall: 9 units
No one is an island: from the casual interactions of day-to-day life to the global markets that supply us with the fruits of our technologies, the fabric of experience is woven out of interaction with other people. This course will introduce you to basic ideas in psychology, economics, and the social sciences that help us understand how this happens. We'll learn about both the mysterious inner world of human experience, and the equally strange and striking social phenomena that they lead to. We'll experiment on ourselves in class to discover unexpected aspects of our own unconscious, and how irrational even the best groups can be. Most importantly, we'll send you out into the world - the physical worlds of CMU and Pittsburgh, and the virtual ones onlineto conduct your own investigations. We know extraordinarily little about the "human animal", and the best way to learn is to go look for ourselves.
Prerequisites: 70-207 or 36-200

88-281 Topics in Law: 1st Amendment

Fall: 9 units
In their firm desire to perfect the new Constitution, which defined and limited the powers and roles of their new government, the founding fathers insisted on explicit statements that would protect the rights of the new nation's citizens. Indeed, the protection of these essential rights in many ways drove and defined their successful rebellion from Britain. This impulse resulted in ten amendments to the Constitution, which we have come to know as the Bill of Rights. The very first (and arguably considered at the time as the most essential) of these was the First Amendment, which we sometimes call the "free speech" amendment to the Constitution. This amendment guarantees every U.S. citizen five freedoms: freedom of religion, speech, press, peaceable assembly, and the freedom to petition the government for redress of grievances. This course examines the historical and philosophical roots of this key constitutional amendment, how it has been fleshed out and defined over time through case law, and the bases of some more recent critics of this amendments and current interpretations.

88-284 Topics of Law: The Bill of Rights

Spring: 9 units
This course examines the history and place of the Bill of Rights in our nation's constitutional framework. It focuses on the historical origins of the U.S. Constitution, of each of the first ten amendments to the Constitution (that we refer to as the "Bill of Rights"), how the meanings and interpretations of these have evolved over time, and what they mean to us today. Each article of the Bill of Rights will be examined in terms of its original intentions, and then through cases that have challenged and been interpreted through the Bill's articles.

88-285 Deconstructing and Dismantling Discrimination

Fall: 9 units
Prejudice and discrimination produce and perpetuate inequitable social outcomes for individuals and groups. However, shifting attitudes does not always change behavior, nor do behavioral shifts always lead to broader social and policy change to bring about societal equity. So, how should we engage in the action needed to address systemic inequality? In this course, students will learn key theories from social psychology, behavioral economics and decision-making, and review research from those disciplines on prejudice and discrimination, including racism, sexism, and classism. With that foundation, students will critically assess policy effectiveness in domains where social inequality persists, including environmental and criminal justice, education, healthcare, housing, and wealth and income. Policies will be examined through readings, podcasts, discussions, and writing activities. In a peer-evaluated final group project, students will propose a policy solution to a specific issue, analyze its efficacy, and present a plan to gain public support for the policy.
Prerequisites: (85-241 or 85-102 or 88-120) and (76-102 or 76-108 or 76-101 or 76-107)

88-290 Confessions, Lies, and Gossip

Intermittent: 9 units
Human beings are social creatures, and sharing thoughts, feelings, and information with others is fundamental to the human experience. We engage in this type of disclosure frequently, often without conscious thought or deliberation. Yet the act of disclosing information is fraught with risk, particularly in the digital age where what we share can be widely accessed and permanently stored. This course aims to cast this ubiquitous act in a new light, investigating many of the behaviors we take for granted, and explaining common counter-normative and suboptimal phenomena, through different theoretical lenses. Why do people share information that they know might prove to be materially damaging or harmful to their reputation? Can gossiping be understood as a prosocial act, benefitting a common good? What types of information are most likely to "go viral"? This course attempts to answer these and many other questions, and to provide students with the perspective and tools necessary to improve their own disclosure decision making.
Prerequisites: 85-102 or 88-120

88-300 Programming and Data Analysis for Social Scientists

Spring: 9 units
This course presents an introduction to computational thinking through practice with data analysis. Students will develop extensive expertise using the statistical programming language R. Designed primarily with social science majors in mind, students will use a variety of data structures to represent information and solve problems. The course is conducted in a "flipped classroom" style, and places a heavy emphasis on hands-on programming and #8212; in every class, students will practice writing computer programs to conduct analysis and explore social science phenomena. Students will develop skills in all facets of the data analysis pipeline, from installing and loading packages to reading-in files to data cleaning, munging, visualization and modeling. The course is primarily intended for students who have limited familiarity with coding, and assumes no previous exposure to R.
Prerequisites: 36-201 or 36-200

88-302 Behavioral Decision Making

Fall and Spring: 9 units
Behavioral decision making is the study of how people make decisions, in terms that can eventually help them to make better decisions. It draws together research from psychology, economics, political science, and management, among other fields. It has applications that range from managing potentially hazardous technologies, to involving patients more fully in the choice of medical procedures, to the design of computer-interactive systems. The course covers behavioral theories of probabilistic inference, intuitive prediction, preference, and decision making. Topics include heuristics and biases in inference and prediction, risk perceptions and attitudes, strategies for combining information from different sources and dealing with conflicting objectives, and the roles of group and emotional processes in decision making. The course emphasizes the mutually reinforcing relationship between theory and application.
Prerequisites: (36-220 or 36-225 or 36-247 or 36-217 or 36-200 or 36-201 or 36-207 or 36-211 or 70-207) and 88-120

88-312 Decision Models and Games

Spring: 9 units
Humans often make decisions in changing and uncertain situations. A car driver entering a new city must adjust decisions rapidly while moving along heavy traffic; firefighter crews entering a burning building must maintain awareness of the development of fire; citizens in a country must change their activities based on the evolution of a pandemic and the restrictions imposed. While challenging, humans are an adaptable species. We plan and re-adjust our plans to changing conditions; we keep aware of potentially new courses of action; and we manage our limited time, information, and attention to changing environments. How do humans make decisions in dynamic situations? This course will explore human decision making as a dynamic process resulting from human interactions with the environment. The course uses decision games to illustrate how humans learn and adapt to changing conditions of choice, and computational models to simulate decision processes and environmental dynamics. Decision Models and Games will provide: (1) foundational perspectives for using models to represent the dynamics of environments and human decision processes; (2) tools to build computational models of human decision making and of dynamic environments; and (3) practical illustrations of how models and games can be used to understand and generate solutions to a wide range of decision problems, from simple choices to large scale consequential decisions.
Prerequisites: 36-201 or 70-207 or 36-200

88-323 Policy in a Global Economy

Fall: 9 units
From the dawn of the New Deal through the presidency of Barack Obama, the U.S. led the development of an open, global system of relatively free trade and global capital flows. In the current political environment, leaders on both the American political left (like Senator Bernie Sanders) and the political right (like Donald Trump), have called into question this bipartisan consensus in favor of freer trade and investment. That turn away from globalization has been accelerated by the COVID-19 pandemic. Was the earlier pro-globalization consensus wrong? Is globalization good or bad for the U.S. economy? What are the impacts of globalization on the rest of the world? How has economic globalization impacted the environment and income inequality in the U.S. and around the world? How should the Biden Administration seek to manage international economic policy? This course provides future policy makers and managers with the knowledge and analytical tools necessary to understand economic globalization and its effects. These issues will be studied using the analytical tools and concepts of international economics. Guest lectures and case studies will provide a range of perspectives on current policy debates. The course will also examine science-based policies that could maximize the benefits and minimize the disruption generated by globalization. The fall 2021 version of the course will examine the global macroeconomic impact of the COVID-19 pandemic and the ways in which international policy coordination and #8212; or lack thereof and #8212; worsened that impact.
Prerequisite: 73-102

Course Website: https://api.heinz.cmu.edu/courses_api/course_detail/90-860/

88-341 Team Dynamics and Leadership

Fall: 9 units
Much of the work in groups and organizations consists of communication. You communicate to get information that will be the basis of decisions, to provide a vision for the people who work for and with you, to coordinate activity, and to sell yourself and your work. The goal of this course is to identify sources of communication problems within an organization and ways to overcome them. To do this requires that we know how communication normally works, what parts are difficult, and how to fix it when it goes wrong. The focus of this course is on providing you with a broad understanding of the way communication operates within dyads, work groups, and organizations. This course is not a practicum in public speaking or writing, although you will get some experience writing, speaking and managing impressions. Rather the intent is to give you theoretical and empirical underpinnings for the communication you will undoubtedly do when you return to work. Readings come from both the research and the managerial literatures. Among the topics considered are managerial communication, persuasion and conformity, self presentation and person perception, social networks. Cases and group projects give you an opportunity to apply what you've learned.
Prerequisites: 36-247 or 36-220 or 36-225 or 70-207 or 36-217 or 36-207 or 36-200 or 36-201

88-342 The Neuroscience of Decision Making

Intermittent: 9 units
Because we are human, feelings provide the basis for reason and rational decision-making. Consider for example, that brain-damaged patients left devoid of emotion struggle to make the most elementary decisions: while they are able layout the pros and cons of a decision, but they are unable to make the final choice. This course will discuss seminal discoveries in affective neuroscience underlying decision-making.
Prerequisites: 85-211 or 88-120

88-344 Systems Analysis: Environmental Policy

Intermittent: 9 units
Systems Analysis: Environmental Policy provides an introduction to how environmental policies have been and can be designed/created, implemented, and evaluated amidst complex information-based, social, political, and cultural processes. The course emphasizes a systems-based methodological approach for addressing the complexities involved in framing, analyzing, and designing an implementation plan for policy construction. The course also explores through landmark and contemporary case studies several dimensions of environmental policy-making: - Contextual, historical, and structural aspects of environmental policy-making at the local, state, federal, and international levels - Use of quantitative and qualitative analytical tools (from core program + new tools) - The process of how policies derive their meanings.

88-360 Behavioral Economics

Fall: 9 units
This course introduces students to behavioral economics, an emerging subfield of economics that incorporates insights from psychology and other social sciences into economics. We will examine evidence on how human behavior systematically departs from the standard assumptions of economics, and then investigate attempts by behavioral economists to improve economic analyses.
Prerequisites: (21-120 or 21-112) and (73-102 or 73-100 or 88-220)

88-365 Behavioral Economics and Public Policy

Fall: 9 units
Economics has up to now been the social science that has been most broadly and deeply involved in public policy. With its rational choice perspective, the economic perspective has tended to favor certain types of policies namely those that enhance the efficiency of market mechanisms and lower the cost of information. In this course we will spend the first several classes reviewing the assumptions, implications for public policy and limitations of the rational choice perspective. The remainder of the course will then be devoted to examining different public policy issues, including saving, health care, crime and drug abuse, through the competing lenses of traditional and behavioral economics.
Prerequisites: 88-220 or 73-100 or 73-102

88-366 Behavioral Economics of Poverty and Development

Intermittent: 9 units
This course will introduce students to the study of economic development and poverty alleviation, with a special focus on recent insights from the intersection of psychology and economics. We will primarily focus on the health, microfinance, agriculture, and education sectors in developing countries. The course will have a methodological component largely centered on using experiments to evaluate interventions and policies that apply to households, small firms, and farms. While we will cover standard economic approaches, we will give extra attention to how a behavioral lens can help in both understanding development issues (e.g. barriers to household risk management) and in designing effective interventions (e.g. the timing of fertilizer sales).
Prerequisites: (73-100 or 73-102 or 88-220) and 36-202

88-367 Behavioral Economics & Field Experiments in Organizations

Spring: 9 units
Behavioral Economics is a sub-field of economics that, relying on insights from psychology and decision-making, aspires to describe actual behavior with greater empirical accuracy and psychological realism than that implied by the standard neoclassical model. In this course, we will investigate the success of this approach in explaining ostensible anomalies in the "wild" such as under-savings for retirement, over-consumption of unhealthy food, extreme aversion to losses among investors, workers, and home-owners, the over-confidence of corporate CEOs and NFL general managers, and the influence of emotions on domestic violence, stock market activity, and risk-taking. We will first document and review the underlying theory for three conceptual departures from the standard model -non-standard preferences (e.g., present-bias, reference dependence), non-standard beliefs (e.g., overconfidence, gambler''s fallacy), and non-standard decision-making (e.g., heuristics, emotions, framing effects)-and then quickly move to assess the evidence for these claims in field settings. We will additionally explore how markets respond to behavioral biases, and discuss recent research in behavioral policy with an emphasis on policies aimed at increasing savings, improving food choice, and heightening program take-up and compliance. The course will be paper-centric and we will review a variety of popular empirical methods from field experiments to quasi-experimental approaches (e.g., estimation through regression-based panel analyses, difference-in-differences, and instrumental variables). Student evaluation will be based on a mix of exams, problem sets, written assignments, and class participation.
Prerequisites: 73-102 and 36-202

88-372 Social and Emotional Brain

Intermittent: 9 units
This course provides an introductory survey of the methods and findings in social and affective neuroscience. Half the course is lecture style and covers the basics of neuroanatomy, neurochemistry, and neuroendocrine systems, as well as a survey of relevant neuroscience methods (neuroimaging, neuropsychological, psychophysiological, transcranial magnetic stimulation, etc.). The other half of the course is more like a seminar, where each week we will discuss a couple seminal empirical papers from the scientific literature. Topics include interpersonal relationships, prosocial behavior, aggression, prejudice, emotion regulation, stress, etc.
Prerequisite: 85-102

88-379 Data-Driven Decision Analysis

Intermittent: 9 units
Business managers and public policymakers who make good decisions are in high demand and are richly rewarded. Increasingly, those decisions must be made in dynamic, data-rich environments. In those environments, having an extensive analytical toolkit and being able to build and use decision models are essential for success. Building on the foundations laid by prior coursework, we will cover advanced analytical topics from the decision sciences with an emphasis on model building. Topics may include utility function elicitation, optimal decision making under uncertainty and imperfect information, valuing flexibility with real options, portfolio theory, artificial intelligence (AI) and evolutionary computation methods, robust decision making, and Monte Carlo simulation and variance reduction methods. The focus of this course is normative, rather than descriptive decision making. The course will make extensive use of Microsoft Excel and students are expected to possess a high level of numeracy upon enrollment. Although we will touch on the theoretical foundations of the material, our primary focus will be on getting our hands dirty by using the techniques covered to build models. The material covered in this class will be taught using real-world problems and place a high value on using messy, often-incomplete real-world data where the strengths and weaknesses of various tools can be evaluated.
Prerequisites: (36-225 or 70-207 or 36-200 or 36-207) and (19-351 or 19-301 or 70-257 or 88-223)

88-397 SDS Undergraduate Research - mini

All Semesters
Students conduct research under the supervision of a Social and amp; Decision Sciences faculty member. Students who wish to engage in research should seek out a faculty member whose interests are appropriate to the research. Prerequisite: Students must also complete an "Independent Study/Research for Credit" form, available from the SDS advisor in Porter 208A. Permission of a faculty sponsor.

88-398 Independent Study

Fall and Spring
Students conduct independent academic study under the supervision of a Social and amp; Decision Sciences faculty member. Students who wish to engage in an independent study should seek out a faculty member whose interests are appropriate to the topic. Students must also complete an "Independent Study/Research for Credit" form, available from the SDS Advisors in Porter 208A and 208G.

88-399 Undergraduate Research

Fall and Spring
Students conduct research under the supervision of a Social and amp; Decision Sciences faculty member. Students who wish to engage in research should seek out a faculty member whose interests are appropriate to the research. Students must also complete an "Independent Study/Research for Credit" form, available from the SDS Advisors in Porter 208A and 208G.

88-411 Rise of the Asian Economies

Intermittent: 9 units
For most of the past quarter century, no region of the world has been more economically dynamic than Asia. This course is designed to provide students with the essential knowledge necessary to evaluate opportunities and risks in Asia. The course will use analytical tools drawn from economics and finance, business cases, and guest lectures to focus on the key strengths that sustained economic growth in East Asia for decades, the weaknesses that undermined that growth in the late 1990s, and what lies ahead. The course will also examine Indian economic growth since the early 1980s, and compare India's experience with that of the East Asian economies. A special focus will be placed on recent developments in India and China and the prospects for continued growth in those countries over the next decade.
Prerequisites: 84-110 or 73-102 or 73-150 or 88-220 or 73-100

88-451 Policy Analysis Senior Project

Spring: 12 units
Students in this course apply the research and analytical methods learned in their other courses to a real-world problem. Students decide how to structure the problem, divide into teams responsible for its different parts, identify and analyze relevant literature, collect data, synthesize their results, and present their conclusions in oral and written form to a review panel of individuals concerned with the problem. Faculty members help them along the way. Performance is based on students' contribution to the process and substance of the class, as observed by the faculty and by their fellow students. One or two such projects is offered every term. A complete list of previous topics is available from the department. Course is open only to seniors in SDS.

88-452 Policy Analysis Senior Project

Fall: 12 units
Students in this course apply the research and analytical methods learned in their other courses to a real-world problem. Students decide how to structure the problem, divide into teams responsible for its different parts, identify and analyze relevant literature, collect data, synthesize their results, and present their conclusions in oral and written form to a review panel of individuals concerned with the problem. Faculty members help them along the way. Performance is based on students' contribution to the process and substance of the class, as observed by the faculty and by their fellow students. One or two such projects is offered every term. A complete list of previous topics is available from the department. Course is open only to seniors in SDS.

88-453 Behavioral Economics Capstone

Spring: 9 units
The Capstone in Behavioral Economics, Policy, and Organizations will work to apply the theories, concepts, and statistical techniques mastered in prior courses to an applied project. Students will work closely both in teams and individually with the instructor on a project that will address a problem posed by an organization or government that behavioral economics can help to solve. Students will work to structure the problem, design an intervention or study, collect and analyze the data, and make recommendations for implementation. Students will manage the project and drive interactions with the client organization.

88-454 Decision Science Capstone

Fall and Spring: 9 units
The Capstone in Decision Science is a seminar that applies the theories, concepts, and statistical techniques mastered in prior courses to an applied project. Students will work closely both in teams and individually with the instructor on a project that will address an applied problem that decision science can help to solve. Students will work to structure the problem, define a focused research question, design a study that addresses the question, collect and analyze the data, and make policy or practice recommendations based on the findings. Students will manage the project, drive the scientific question and approach, and make a formal presentation to a panel of experts.
Prerequisite: 88-302

88-499 Advanced Undergraduate Research

Fall and Spring
Students conduct research at an advanced level under the supervision of a Social and amp; Decision Sciences faculty member. Students who wish to engage in advanced research should seek out a faculty member whose interests are appropriate to the research. Students must also complete an "Independent Study/Research for Credit" form, available from the SDS Advisors in Porter 208A and 208G.

88-505 Undergraduate Internship

All Semesters
An internship is an approved and monitored work experience than can be related to an academic field of study through active reflection and specific learning goals. Students must work at least 10 hours per week for the semester at the internship. Additionally, students will also keep in regular contact with a faculty member in Social and Decision Sciences, who will assign and evaluate academic work. Internships are available for 1-9 units, depending on the type and amount of academic work produced. Students are responsible for finding their own internships and faculty sponsors, although assistance is available in the department. Students must also complete an "Internship Learning Agreement" form, available from the SDS Advisors in Porter 208H and 208G.

88-631 Thinking in Person vs. Thinking Online

Intermittent: 9 units
Being online changes how we think. Different media lead us to ask different questions, remember (or forget) different information, attend to different details, and interact with other people in different ways. These types of thinking aren't inherently better or worse, but they may be better or worse for facilitating specific goals. Too often, we use a particular medium/technology without considering how it will influence our thinking. This can lead us to be less efficient or less effective at a task than we otherwise might be, or can qualitatively change the nature of our outcomes. In this class, we will explore how the media we use affects the character of our thinking, so as to enable students to make mindful and deliberate choices about how to interact with media in ways that support the type of thinking desired and appropriate for their goals. Moreover, we will examine how to optimize media for specific goals in important applied domains, such as education, medicine, policy, child-rearing, and dating.

Department of Statistics and Data Science

Rebecca Nugent, Department Head

Peter Freeman, Director of Undergraduate Studies

Samantha Nielsen, Associate Director of Academic Programs

Amanda Mitchell, Lead Senior Academic Advisor

Glenn Clune, Academic Program Manager

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Peter Long, Academic Advisor

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Overview

Uncertainty is inescapable: randomness, measurement error, deception, and incomplete or missing information all complicate our lives. Statistics is the science and art of making predictions and decisions in the face of uncertainty. Statistical issues are central to big questions in public policy, law, medicine, industry, computing, technology, finance, and science. Indeed, the tools of statistics apply to problems in almost every area of human activity where data are collected.

Statisticians have diverse skills in computing, mathematics, decision making, designing experiments, forecasting, and interpreting and communicating analysis results. Moreover, effective statisticians actively collaborate with people in other fields and, in the process, learn about other fields. Statistics & Data Science students who master core concepts and collaboration are highly sought after in the marketplace.

Recent statistics majors at Carnegie Mellon have taken jobs at leading companies in many fields, including the National Economic Research Association, Boeing, Morgan Stanley, Deloitte, Rosetta Marketing Group, Nielsen, Proctor & Gamble, Accenture, and Goldman Sachs. Others have taken research positions at the National Security Agency, the U.S. Census Bureau, and the Science and Technology Policy Institute, or worked for Teach for America. Many of our students also go on to graduate study at some of the top programs in the country including Carnegie Mellon, Harvard, MIT, Yale, NYU, Penn, Johns Hopkins, Duke, Michigan, Chicago, Northwestern, Washington, Stanford, and California.

The Department and Faculty

The Department of Statistics & Data Science at Carnegie Mellon University is world-renowned for its contributions to statistical theory and practice. Research in the department spans the gamut from pure mathematics to the hottest frontiers of science. Current research projects are helping make fundamental advances in neuroscience, cosmology, public policy, finance, and genetics.

The faculty members are recognized around the world for their expertise and have garnered many prestigious awards and honors. (For example, three members of the faculty have been awarded the COPSS medal, the highest honor given by professional statistical societies.) At the same time, the faculty is firmly dedicated to undergraduate education. The entire faculty, junior and senior, teach courses at all levels. The faculty are accessible and are committed to involving undergraduates in research.

The Department augments all these strengths with a friendly, energetic working environment and exceptional computing resources. Talented graduate students join the department from around the world, and add a unique dimension to the department's intellectual life. Faculty, graduate students, and undergraduates interact regularly.

How to Take Part

There are many ways to get involved in statistics at Carnegie Mellon:

- The Bachelor of Science in Statistics in the Dietrich College of Humanities and Social Sciences (DC) is a broad-based, flexible program that helps you master both the theory and practice of statistics. The program can be tailored to prepare you for later graduate study in statistics or to complement your interests in almost any field, including psychology, physics, biology, history, business, information systems, and computer science.
- The Minor (or Additional Major) in Statistics is a useful complement to a (primary) major in another department or college. Almost every field of inquiry must grapple with statistical problems, and the tools of statistical theory and data analysis you will develop in the Statistics minor (or Additional Major) will give you a critical edge.
- The Bachelor of Science in Economics and Statistics provides an interdisciplinary course of study aimed at students with a strong interest in the empirical analysis of economic data. Jointly administered by the Department of Statistics & Data Science and the Undergraduate Economics Program, the major's curriculum provides students with a solid foundation in the theories and methods of both fields. (See Dietrich College Interdepartmental Majors as well later in this section)
- The Bachelor of Science in Statistics and Machine Learning is a program housed in the Department of Statistics & Data Science and is jointly administered with the Department of Machine Learning. In this major students take courses focused on skills in computing, mathematics, statistical theory, and the interpretation and display of complex data. The program is geared toward students interested in statistical computation, data science, and "big data" problems.
- The Statistics Concentration and the Operations Research and Statistics Concentration in the Mathematical Sciences Major (see Department of Mathematical Sciences) are administered by the Department of Mathematical Sciences with input from the Department of Statistics & Data Science.
- Non-majors are eligible to take most of our courses, and indeed, they are required to do so by many programs on campus. Such courses offer one way to learn more about the Department of Statistics & Data Science and the field in general.

Curriculum

Statistics consists of two intertwined threads of inquiry: statistical theory and data analysis. The former uses probability theory to build and analyze mathematical models of data in order to devise methods for making effective predictions and decisions in the face of uncertainty. The latter involves techniques for extracting insights from complicated data, designs for accurate measurement and comparison, and methods for checking the validity of theoretical assumptions. Statistical theory informs data analysis and vice versa. The Department of Statistics & Data Science curriculum follows both of these threads and helps students develop required skills.

Throughout the sections of this catalog, we describe the requirements for the Major in Statistics (the core major as well as the Mathematics and Neuroscience tracks), followed by the requirements for the Major in Economics and Statistics, the Major in Statistics and Machine Learning, and the Minor in Statistics.

Note: We recommend that you use the information provided below as a general guideline, and then schedule a meeting with a Statistics Undergraduate Advisor (statadvising@stat.cmu.edu) to discuss the requirements in more detail, and build a program that is tailored to your strengths and interests.

B.S. in Statistics

Peter Freeman, *Undergraduate Program Director*

Location: Baker Hall 229
pfreeman@andrew.cmu.edu

Amanda Mitchell, *Lead Senior Academic Advisor*

Glenn Clune, *Academic Program Manager*

Sylvie Aubin, *Academic Program Manager*

Peter Long, *Academic Advisor*

Location: Baker Hall 129
statadvising@andrew.cmu.edu (statadvising@stat.cmu.edu)

Students in the Bachelor of Science in Statistics program develop and master a wide array of skills in computing, mathematics, statistical theory, and the interpretation and display of complex data. In addition, Statistics majors gain experience in applying statistical tools to real problems in other fields and learn the nuances of interdisciplinary collaboration. The requirements for the B.S. in Statistics are detailed below and are organized by categories #1-7.

Curriculum

1. Mathematical Foundations (Prerequisites) 29–42 units

Mathematics is the language in which statistical models are described and analyzed, so some experience with basic calculus and linear algebra is an important component for anyone pursuing a program of study in Statistics & Data Science.

Calculus*

Complete one of the two following sequences of mathematics courses at Carnegie Mellon, each of which provides sufficient preparation in calculus:

Sequence 1

21-111	Calculus I	10
21-112	Calculus II	10
And one of the following three courses:		
21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	10
21-268	Multidimensional Calculus	11

Sequence 2

21-120	Differential and Integral Calculus	10
And one of the following three courses:		
21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	10
21-268	Multidimensional Calculus	11

Notes:

- Passing the Mathematical Sciences 21-120 assessment test is an acceptable alternative to completing 21-120.

Linear Algebra**

Complete *one* of the following three courses:

21-240	Matrix Algebra with Applications	10
21-241	Matrices and Linear Transformations	11
21-242	Matrix Theory	11

* It is recommended that students complete the calculus requirement during their freshman year.

**The linear algebra requirement needs to be completed before taking 36-401 Modern Regression.

21-241 and 21-242 are intended only for students with a very strong mathematical background.

2. Data Analysis 36-45 units

Data analysis is the art and science of extracting insight from data. The art lies in knowing which displays or techniques will reveal the most interesting features of a complicated data set. The science lies in understanding the various techniques and the assumptions on which they rely. Both aspects require practice to master.

The Beginning Data Analysis courses give a hands-on introduction to the art and science of data analysis. The courses cover similar topics but differ slightly in the examples they emphasize. 36-200 draws examples from many fields and satisfies the Dietrich College Core Requirement in Statistical Reasoning. This course is therefore recommended for students in the college. (Note: a score of 5 on the Advanced Placement [AP] Exam in Statistics may be used to waive this requirement). 36-220 emphasizes examples in engineering.

The Intermediate Data Analysis courses build on the principles and methods covered in the introductory course, and more fully explore specific types of data analysis methods in more depth.

The Advanced Data Analysis courses draw on students' previous experience with data analysis and understanding of statistical theory to develop advanced, more sophisticated methods. These core courses involve extensive analysis of real data with emphasis on developing the oral and writing skills needed for communicating results.

Sequence 1 (For students beginning their freshman or sophomore year)

Beginning*

Choose *one* of the following courses:

36-200	Reasoning with Data *	9
36-220	Engineering Statistics and Quality Control	9

*A score of 5 on the Advanced Placement (AP) Exam in Statistics may be used to waive this requirement. 36-220 emphasizes examples in engineering and Architecture.

Note: Students who enter the program with credit for 36-235 or 36-236 should discuss options with an advisor.

Intermediate*

Choose *one* of the following courses:

36-202	Methods for Statistics & Data Science **	9
36-309	Experimental Design for Behavioral & Social Sciences	9
36-290	Introduction to Statistical Research Methodology	9
* Or an extra Advanced Data Analysis Elective		
** Must take prior to 36-401, if not, an additional Advanced Data Analysis Elective is required		

Advanced Data Analysis Elective

Choose <u>one</u> of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-313	Statistics of Inequality and Discrimination	9
36-315	Statistical Graphics and Visualization	9
36-318	Introduction to Causal Inference	9
36-460	Special Topics: Sports Analytics	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Statistical Machine Learning	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Psychometrics: A Statistical Modeling Approach	9
36-465	Special Topics: Conceptual Foundations of Statistical Learning	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-469	Special Topics: Statistical Genomics and High Dimensional Inference	9
36-470	Special Topics: Statistical Methods in Health Sciences	9
36-471	Special Topics: Time Series	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

Students can also take a second 36-46x or 36-47x (see section #5).

<u>and</u> take the following *two* courses:

36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9

Sequence 2 (For students beginning later in their college career)

Advanced Data Analysis Electives

Choose <u>two</u> of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-313	Statistics of Inequality and Discrimination	9
36-315	Statistical Graphics and Visualization	9
36-318	Introduction to Causal Inference	9
36-460	Special Topics: Sports Analytics	9
36-461	Special Topics: Statistical Methods in Epidemiology	9

36-462	Special Topics: Statistical Machine Learning	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Psychometrics: A Statistical Modeling Approach	9
36-465	Special Topics: Conceptual Foundations of Statistical Learning	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-469	Special Topics: Statistical Genomics and High Dimensional Inference	9
36-470	Special Topics: Statistical Methods in Health Sciences	9
36-471	Special Topics: Time Series	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

**All Special Topics are not offered every semester, and new Special Topics are regularly added. See section 5 for details.

and take the following *two* courses:

36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9

3. Probability Theory and Statistical Theory 18 units

The theory of probability gives a mathematical description of the randomness inherent in our observations. It is the language in which statistical models are stated, so an understanding of probability is essential for the study of statistical theory. Statistical theory provides a mathematical framework for making inferences about unknown quantities from data. The theory reduces statistical problems to their essential ingredients to help devise and evaluate inferential procedures. It provides a powerful and wide-ranging set of tools for dealing with uncertainty.

To satisfy the theory requirement take the following two courses:

Take one of the following courses:		
36-235	Probability and Statistical Inference I *	9
36-225	Introduction to Probability Theory	9
And one of the following three courses:		
36-236	Probability and Statistical Inference II **	9
36-226	Introduction to Statistical Inference	9
36-326	Mathematical Statistics (Honors)	9

*It is possible to substitute 36-218, 36-219, 36-225, 15-259 or 21-325 for 36-235. 36-235 is the standard (and recommended) introduction to probability, 36-219 is tailored for engineers and computer scientists, 36-218 and 15-259 are more mathematically rigorous classes for Computer Science students and more mathematically advanced (students need advisor approval to enroll), and 21-325 is a rigorous probability theory course offered by the Department of Mathematics.)

**It is possible to substitute 36-226 or 36-326 (honors course) for 36-236 . 36-236 is the standard (and recommended) introduction to statistical inference.

Please note that students who complete 36-235 are expected to take 36-236 to complete their theory requirements. Students who choose to take 36-225 instead will be required to take 36-226 afterward. They will not be eligible to take 36-236.

Comment:

(i) In order to meet the prerequisite requirements, a grade of at least a C is required in 36-235 (or equivalent), 36-236 (or equivalent), and 36-401.

4. Statistical Computing 19 to 21 units

Fundamental to the practice of statistics and data science is the ability to effectively code data processing and analysis tasks. Within the domain of statistics, the use of the programming language R is ubiquitous, and thus we expose students to it throughout the curriculum (and in depth in Statistical Computing). Within the larger domain of data science, the use of the programming language Python is also ubiquitous, and thus we require all majors to gain, at a minimum, basic competency in the language by taking either Principles of Computing, or Fundamentals of Programming and Computer Science. We would advise those students who are considering receiving course credit for one of these two courses given their score on the AP Computer Science A exam to actually take one (or both) of them at Carnegie Mellon instead, as within data science as a whole Python is far more widely used than Java.

Take one of the following two courses:		
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
Complete the following course:		
36-350	Statistical Computing	9

5. Special Topics 9 units

The Department of Statistics & Data Science offers advanced courses that focus on specific statistical applications or advanced statistical methods. These courses are numbered 36-46x (36-461, 36-462, etc.) or 36-47x (36-470, 36-471, etc.) The objective of the course is to expose students to important topics in statistics and/or interesting applications which are not part of the standard undergraduate curriculum. Note that all Special Topics are not offered every semester, and new Special Topics are regularly added.

To satisfy the Special Topics requirement choose *one* of the **36-46x or 36-47x** courses (which are 9 units).

Note: All 36-46x and 36-47x courses require 36-401 as a prerequisite or corequisite.

6. Statistical Elective 9–12 units

Students are required to take one elective which can be within or outside the Department of Statistics & Data Science. **Courses within Statistics & Data Science** can be any 300 or 400 level course (that is not used to satisfy any other requirement for the statistics major).

The following is a partial list of **courses outside Statistics & Data Science** that qualify as electives as they provide the intellectual infrastructure that will advance the student's understanding of statistics and its applications. Other courses may qualify as well; consult with an advisor.

15-121	Introduction to Data Structures	10
15-122	Principles of Imperative Computation	12
10-301	Introduction to Machine Learning	12
10-315	Introduction to Machine Learning (SCS Majors)	12
15-388	Practical Data Science	9
21-127	Concepts of Mathematics	12
21-260	Differential Equations	9
21-292	Operations Research I	9
21-301	Combinatorics	9
21-355	Principles of Real Analysis I	9
80-220	Philosophy of Science	9
80-221	Philosophy of Social Science	9
80-310	Formal Logic	9
85-310	Research Methods in Cognitive Psychology	9
85-320	Research Methods in Developmental Psychology	9
85-340	Research Methods in Social Psychology	9
88-223	Decision Analysis	12
88-302	Behavioral Decision Making	9

Note: Additional prerequisites are required for some of these courses. Students should carefully check the course descriptions to determine if additional prerequisites are necessary.

7. Concentration Area

Self-Defined Concentration Area (with advisor's approval) 36 UNITS

The power of statistics, and much of the fun, is that it can be applied to answer such a wide variety of questions in so many different fields. A critical part of statistical practice is understanding the questions being asked so that appropriate methods of analysis can be used. Hence, a critical part of statistical training is to gain experience applying abstract tools to real problems.

The Concentration Area is a set of four related courses outside of Statistics & Data Science that prepares the student to deal with statistical aspects of problems that arise in another field. These courses are usually drawn from a *single* discipline of interest to the student and must be approved by your Statistics Undergraduate Director. While these courses are not in Statistics & Data Science, the concentration area must complement the overall degree.

For example, students intending to pursue careers in the health or biomedical sciences could take further courses in biology or chemistry, or students intending to pursue graduate work in statistics could take further courses in advanced mathematics.

The concentration area can be fulfilled with a minor or additional major, but not *all* minors and additional majors fulfill this requirement. Please make sure to consult your Statistics Undergraduate advisor *prior* to pursuing courses for the concentration area. Once the concentration area is approved, any changes made to the previously agreed upon coursework require re-approval by an advisor.

Concentration Approval Process

- Submit the below materials to your Undergraduate Statistics Advisor:
    - List of possible coursework to fulfill the concentration*
    - 150-200 word essay describing how the proposed courses complement the B.S. in Statistics degree.

* These courses can be amended later but must be re-approved by your Statistics Undergraduate Advisor if amended.

* Note: The concentration/track requirement is only for students whose *primary* major is statistics and has no other additional major or minor. The requirement does not apply for students who pursue an *additional* major in statistics.

Total number of units for the major	**156-183* Units**
Total number of units for the degree	**360 Units**

*Note: This number can vary depending on the courses chosen for the concentration area that a student takes. Speak with an academic advisor for more details.

Recommendations

Students in the Dietrich College of Humanities and Social Sciences who wish to major or minor in Statistics are advised to complete both the calculus requirement (one Mathematical Foundations calculus sequence) and the Beginning Data Analysis course 36-200 by the end of their freshman year.

The linear algebra requirement is a prerequisite for the course 36-401. It is therefore essential that students complete this requirement by their junior years at the latest.

Recommendations for Prospective Ph.D. Students

Students interested in pursuing a Ph.D. in Statistics or Biostatistics (or related programs) after completing their undergraduate degree are strongly recommended to pursue the **Mathematical Statistics Track** or to take additional Mathematics courses. Although 21-240 Matrix Algebra with Applications is recommended for Statistics majors, students interested in PhD programs should consider taking 21-241 Matrices and Linear Transformations or 21-242 Matrix Theory instead. Additional courses to consider are 21-228 Discrete Mathematics, 21-341 Linear Algebra, 21-355 Principles of Real Analysis I, and 21-356 Principles of Real Analysis II.

Additional Major in Statistics

Students who elect the B.S. in Statistics as a second or third major must fulfill all Statistics degree requirements except for the Concentration Area requirement. Majors in many other programs would naturally complement a statistics major, including Tepper's undergraduate business program, Social and Decision Sciences, Policy and Management, and Psychology.

With respect to double-counting courses, it is departmental policy that students must have at least five statistics courses that do not count for their primary major. If students do not have at least five, they will need to take additional advanced data analysis electives.

Students are advised to begin planning their curriculum (with appropriate advisors) as soon as possible. This is particularly true if the other major has a complex set of requirements and prerequisites or when many of the other major's requirements overlap with the requirements for the B.S. in Statistics.

Substitutions and Waivers

Many departments require Statistics & Data Science courses as part of their Major or Minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department of Statistics & Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics & Data Science. In many of these cases, the student will need to take additional courses to satisfy major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Statistics.

Research

The Statistics & Data Science program encourages students to gain research experience. Opportunities within the department include Summer Undergraduate Research Apprenticeships (SURA), run in association with the university's Office of Undergraduate Research and Scholar Development, and the departmental capstone courses 36-490 Undergraduate Research or 36-497 Corporate Capstone Project. (Note that these courses require an application.) Additionally, students can pursue independent study. For those students who maintain a quality point average of 3.25 overall or above, there is also the Dietrich College Senior Honors Program (p.).

The faculty in the Statistics & Data Science department largely work within the domains of statistical theory and methodological development, areas that require advanced mathematical training. Thus we encourage students to search broadly for research opportunities: faculty, post-doctoral researchers, and graduate students in many departments throughout the university have data to analyze and would welcome the help of undergraduate statistics students.

Sample Programs

The following sample programs illustrate three (of many) ways to satisfy the requirements for the B.S. in Statistics. However, keep in mind that the program is flexible enough to support *many* other possible schedules and to emphasize a wide variety of interests.

The first schedule uses calculus sequence 1.

The second schedule is an example of the case when a student enters the program through 36-235 and 36-236 (and therefore skips the beginning data analysis sequence). This schedule has more emphasis on statistical theory and probability.

Schedule 1

First-Year		**Second-Year**	
Fall	**Spring**	**Fall**	**Spring**
36-200 Reasoning with Data	36-202 Methods for Statistics & Data Science	36-235 Probability and Statistical Inference I	36-236 Probability and Statistical Inference II
21-111 Calculus I	21-112 Calculus II	21-256 Multivariate Analysis	36-350 Statistical Computing
-----	One of the following two courses:	Course toward concentration	21-240 Matrix Algebra with Applications
-----	15-110 Principles of Computing	-----	-----
	15-112 Fundamentals of Programming and Computer Science		

Third-Year		**Fourth-Year**	
Fall	**Spring**	**Fall**	**Spring**
36-401 Modern Regression	36-402 Advanced Methods for Data Analysis	Course toward concentration	Course toward concentration
36-3xx or 36-4xx Advanced Data Analysis Elective	36-46x Special Topics course	-----	-----
Course toward concentration	Course toward concentration	-----	-----
-----	-----	-----	-----

Schedule 2

First-Year		**Second-Year**	
Fall	**Spring**	**Fall**	**Spring**
21-120 Differential and Integral Calculus	21-256 Multivariate Analysis	36-235 Probability and Statistical Inference I	36-236 Probability and Statistical Inference II
36-200 Reasoning with Data	One of the following two courses:	-----	21-240 Matrix Algebra with Applications
-----	15-110 Principles of Computing	-----	-----
-----	15-112 Fundamentals of Programming and Computer Science	-----	-----

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
36-350 Statistical Computing	36-402 Advanced Methods for Data Analysis	36-46x Special Topics	Course toward concentration
36-401 Modern Regression	Course toward concentration	Course toward concentration	36-3xx or 36-4xx Advanced Data Analysis Elective
36-3xx or 36-4xx Advanced Data Analysis Elective	-----	-----	-----
Course toward concentration	-----	-----	-----

B.S. in Statistics (Mathematical Sciences Track)

Peter Freeman, *Undergraduate Program Director*

Location: Baker Hall 229
pfreeman@andrew.cmu.edu

Amanda Mitchell, *Lead Senior Academic Advisor*

Glenn Clune, *Academic Program Manager*

Sylvie Aubin, *Academic Program Manager*

Peter Long, *Academic Advisor*

Location: Baker Hall 129
statadvising@andrew.cmu.edu (statadvising@stat.cmu.edu)

Students in the Bachelor of Science in Statistics (Mathematical Sciences Track) program develop and master a wide array of skills in computing, mathematics, statistical theory, and the interpretation and display of complex data. In addition, Statistics majors gain experience in applying statistical tools to real problems in other fields and learn the nuances of interdisciplinary collaboration. The requirements for the B.S. in Statistics (Mathematical Sciences Track) are detailed below and are organized by categories #1-#7.

Curriculum

1. Mathematical Foundations (Prerequisites) 39-52 units

Mathematics is the language in which statistical models are described and analyzed, so some experience with basic calculus and linear algebra is an important component for anyone pursuing a program of study in Statistics & Data Science.

Calculus*

Complete one of the two following sequences of mathematics courses at Carnegie Mellon, each of which provides sufficient preparation in calculus:

Sequence 1

21-111	Calculus I	10
21-112	Calculus II	10
21-122	Integration and Approximation	10
And one of the following three courses:		
21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	10
21-268	Multidimensional Calculus	11

Sequence 2

21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
And one of the following three courses:		
21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	10
21-268	Multidimensional Calculus	11

Notes:

- Passing the Mathematical Sciences 21-120 assessment test is an acceptable alternative to completing 21-120.
- 21-122 is a required prerequisite for 21-355 Principles of Real Analysis I, a requirement for the Mathematical Sciences Track major concentration.

Linear Algebra**

Complete *one* of the following three courses:

21-240	Matrix Algebra with Applications	10
21-241	Matrices and Linear Transformations	11
21-242	Matrix Theory	11

* It is recommended that students complete the calculus requirement during their freshman year.

**The linear algebra requirement needs to be completed before taking 36-401 Modern Regression.

21-241 and 21-242 are intended only for students with a very strong mathematical background.

2. Data Analysis 36-45 units

Data analysis is the art and science of extracting insight from data. The art lies in knowing which displays or techniques will reveal the most interesting features of a complicated data set. The science lies in understanding the various techniques and the assumptions on which they rely. Both aspects require practice to master.

The Beginning Data Analysis courses give a hands-on introduction to the art and science of data analysis. The courses cover similar topics but differ slightly in the examples they emphasize. 36-200 draws examples from many fields and satisfies the Dietrich College Core Requirement in Statistical Reasoning. This course is therefore recommended for students in the college. (Note: a score of 5 on the Advanced Placement [AP] Exam in Statistics may be used to waive this requirement). 36-220 emphasizes examples in engineering.

The Intermediate Data Analysis courses build on the principles and methods covered in the introductory course and more fully explore specific types of data analysis methods in more depth.

The Advanced Data Analysis courses draw on students' previous experience with data analysis and understanding of statistical theory to develop advanced, more sophisticated methods. These core courses involve extensive analysis of real data with emphasis on developing the oral and writing skills needed for communicating results.

Sequence 1 (For students beginning their freshman or sophomore year)

Beginning*

Choose *one* of the following courses:

36-200	Reasoning with Data *	9
36-220	Engineering Statistics and Quality Control	9

*A score of 5 on the Advanced Placement (AP) Exam in Statistics may be used to waive this requirement. 36-220 emphasizes examples in engineering and Architecture.

Note: Students who enter the program with 36-235 or 36-236 should discuss options with an advisor.

Intermediate*

Choose *one* of the following courses:

36-202	Methods for Statistics & Data Science **	9
36-309	Experimental Design for Behavioral & Social Sciences	9
36-290	Introduction to Statistical Research Methodology	9
*Or an extra Advanced Data Analysis Elective		
** Must take prior to 36-401, if not, an additional Advanced Data Analysis Elective is required		

Advanced Data Analysis Elective

Choose *one* of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-313	Statistics of Inequality and Discrimination	9
36-315	Statistical Graphics and Visualization	9
36-318	Introduction to Causal Inference	9
36-460	Special Topics: Sports Analytics	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Statistical Machine Learning	9
36-463	Special Topics: Multilevel and Hierarchical Models	9

36-464	Special Topics: Psychometrics: A Statistical Modeling Approach	9
36-465	Special Topics: Conceptual Foundations of Statistical Learning	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-469	Special Topics: Statistical Genomics and High Dimensional Inference	9
36-470	Special Topics: Statistical Methods in Health Sciences	9
36-471	Special Topics: Time Series	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

Students can also take a second 36-46x (see section #5).

and take the following *two* courses:

36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9

Sequence 2 (For students beginning later in their college career)

Advanced

Choose *two* of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-313	Statistics of Inequality and Discrimination	9
36-315	Statistical Graphics and Visualization	9
36-318	Introduction to Causal Inference	9
36-460	Special Topics: Sports Analytics	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Statistical Machine Learning	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Psychometrics: A Statistical Modeling Approach	9
36-465	Special Topics: Conceptual Foundations of Statistical Learning	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-469	Special Topics: Statistical Genomics and High Dimensional Inference	9
36-470	Special Topics: Statistical Methods in Health Sciences	9
36-471	Special Topics: Time Series	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

**All Special Topics are not offered every semester, and new Special Topics are regularly added. See section 5 for details.

and take the following *two* courses:

36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9

3. Probability Theory and Statistical Theory 18 units

The theory of probability gives a mathematical description of the randomness inherent in our observations. It is the language in which statistical models are stated, so an understanding of probability is essential for the study of statistical theory. Statistical theory provides a mathematical framework for making inferences about unknown quantities from data. The theory reduces statistical problems to their essential ingredients to help devise and evaluate inferential procedures. It provides a powerful and wide-ranging set of tools for dealing with uncertainty.

To satisfy the theory requirement take the following two courses:

Take one of the following courses:		
36-235	Probability and Statistical Inference I *	9
36-225	Introduction to Probability Theory	9
And one of the following three courses:		
36-226	Introduction to Statistical Inference	9
36-236	Probability and Statistical Inference II **	9
36-326	Mathematical Statistics (Honors)	9

*It is possible to substitute 36-218, 36-219, 36-225, 15-259, or 21-325 for 36-235. 36-235 is the standard (and recommended) introduction to probability, 36-219 is tailored for engineers and computer scientists, 36-218 and 15-259 are more mathematically rigorous classes for Computer Science students and more mathematically advanced (students need prior approval to enroll), and 21-325 is a rigorous probability theory course offered by the Department of Mathematics).

**It is possible to substitute 36-226 or 36-326 (honors course) for 36-236. 36-236 is the standard (and recommended) introduction to statistical inference.

Please note that students who complete 36-235 are expected to take 36-236 to complete their theory requirements. Students who choose to take 36-225 will be required to take 36-226 afterward. They will not be eligible to take 36-236.

Comment:

(i) In order to meet the prerequisite requirements, a grade of at least a C is required in 36-235 (or equivalent), 36-236 (or equivalent), and 36-401.

4. Statistical Computing 19 to 21 units

Fundamental to the practice of statistics and data science is the ability to effectively code data processing and analysis tasks. Within the domain of statistics, the use of the programming language R is ubiquitous, and thus we expose students to it throughout the curriculum (and in depth in Statistical Computing). Within the larger domain of data science, the use of the programming language Python is also ubiquitous, and thus we require all majors to gain, at a minimum, basic competency in the language by taking either Principles of Computing, or Fundamentals of Programming and Computer Science. We would advise those students who are considering receiving course credit for one of these two courses given their score on the AP Computer Science A exam to actually take one (or both) of them at Carnegie Mellon instead, as within data science as a whole Python is far more widely used than Java.

Take one of the following two courses:		
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
Complete the following course:		
36-350	Statistical Computing	9

5. Special Topics 9 units

The Department of Statistics & Data Science offers advanced courses that focus on specific statistical applications or advanced statistical methods. These courses are numbered 36-46x (36-461, 36-462, etc.) or 36-47x (36-470, 36-471, etc.). The objective of the course is to expose students to important topics in statistics and/or interesting applications which are not part of the standard undergraduate curriculum. Note that all Special Topics are not offered every semester, and new Special Topics are regularly added.

To satisfy the Special Topics requirement choose *one* of the **36-46x or 36-47x** courses (which are 9 units).

Note: All 36-46x and 36-47x courses require 36-401 as a prerequisite or corequisite.

6. Statistical Elective 9–12 units

Students are required to take one elective which can be within or outside the Department of Statistics & Data Science. **Courses within Statistics & Data Science** can be any 300 or 400 level course (that is not used to satisfy any other requirement for the statistics major).

The following is a partial list of **courses outside Statistics & Data Science** that qualify as electives as they provide the intellectual infrastructure that will advance the student's understanding of statistics and its applications. Other courses may qualify as well; consult with your Statistics Undergraduate Advisor.

15-121	Introduction to Data Structures	10
15-122	Principles of Imperative Computation	12
10-301	Introduction to Machine Learning	12
10-315	Introduction to Machine Learning (SCS Majors)	12
15-388	Practical Data Science	9
21-260	Differential Equations	9
21-292	Operations Research I	9

21-301	Combinatorics	9
21-355	Principles of Real Analysis I	9
80-220	Philosophy of Science	9
80-221	Philosophy of Social Science	9
80-310	Formal Logic	9
85-310	Research Methods in Cognitive Psychology	9
85-320	Research Methods in Developmental Psychology	9
85-340	Research Methods in Social Psychology	9
88-223	Decision Analysis	12
88-302	Behavioral Decision Making	9

Note: Additional prerequisites are required for some of these courses. Students should carefully check the course descriptions to determine if additional prerequisites are necessary.

Mathematical Statistics Track 46–52 units

21-127	Concepts of Mathematics	12
21-355	Principles of Real Analysis I	9
36-410	Introduction to Probability Modeling	9

Note: 21-122 is a prerequisite for 21-355 and must be completed before students can register for the course.

And *two* of the following:

21-228	Discrete Mathematics	9
21-257	Models and Methods for Optimization	9
or 21-292	Operations Research I	
21-301	Combinatorics	9
21-344	Numerical Linear Algebra	9
21-356	Principles of Real Analysis II	9
21-373	Algebraic Structures	9
36-700	Probability and Mathematical Statistics	12

Total number of units for the major	**177-209 Units***
Total number of units for the degree	**360 Units**

*Note: This number can vary depending on the courses chosen for the concentration area that a student takes. Speak with an academic advisor for more details.

Recommendations

Students in the Dietrich College of Humanities and Social Sciences who wish to major or minor in Statistics are advised to complete both the calculus requirement (one Mathematical Foundations calculus sequence) and the Beginning Data Analysis course 36-200 by the end of their freshman year.

The linear algebra requirement is a prerequisite for the course 36-401. It is therefore essential that students complete this requirement by their junior years at the latest.

Recommendations for Prospective Ph.D. Students

Students interested in pursuing a Ph.D. in Statistics or Biostatistics (or related programs) after completing their undergraduate degree are strongly recommended to pursue the **Mathematical Statistics Track**.

Additional Major in Statistics (Mathematical Science Track)

Students who elect the B.S. in Statistics (Mathematical Science Track) as an additional major must fulfill all Statistics (Mathematical Science Track) degree requirements. With respect to double-counting courses, it is departmental policy that students must have at least six courses [three Statistics courses (36-xxx) and three Mathematical Sciences Track electives] that do not count for their primary major. If students do not have at least six, they typically take additional advanced data analysis and/or math electives.

Students are advised to begin planning their curriculum (with appropriate advisors) as soon as possible. This is particularly true if the other major has a complex set of requirements and prerequisites or when many of the other major's requirements overlap with the requirements for a B.S. in Statistics (Mathematical Science Track).

Substitutions and Waivers

Many departments require Statistics & Data Science courses as part of their Major or Minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department of Statistics & Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

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Research

The Statistics & Data Science program encourages students to gain research experience. Opportunities within the department include Summer Undergraduate Research Apprenticeships (SURA), run in association with the university's Office of Undergraduate Research and Scholar Development, and the departmental capstone courses 36-490 Undergraduate Research or 36-497 Corporate Capstone Project. (Note that these courses require an application.) Additionally, students can pursue independent study. For those students who maintain a quality point average of 3.25 overall or above, there is also the Dietrich College Senior Honors Program (p.).

The faculty in the Statistics & Data Science department largely work within the domains of statistical theory and methodological development, areas that require advanced mathematical training. Thus we encourage students to search broadly for research opportunities: faculty, post-doctoral researchers, and graduate students in many departments throughout the university have data to analyze and would welcome the help of undergraduate statistics students.

Sample Programs

The following sample programs illustrate three (of many) ways to satisfy the requirements for the B.S. in Statistics (Mathematical Sciences Track). However, keep in mind that the program is flexible enough to support *many* other possible schedules and to emphasize a wide variety of interests.

The first schedule uses calculus sequence 1.

The second schedule is an example of the case when a student enters the program through 36-235 and 36-236 (and therefore skips the intermediate data analysis course). This schedule has more emphasis on statistical theory and probability.

SCHEDULE 1

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
36-200 Reasoning with Data	36-202 Methods for Statistics & Data Science	21-122 Integration and Approximation	36-236 Probability and Statistical Inference II
21-111 Calculus I	21-256 Multivariate Analysis	21-127 Concepts of Mathematics	36-350 Statistical Computing
-----	21-112 Calculus II	36-235 Probability and Statistical Inference I	21-240 Matrix Algebra with Applications
-----	-----	One of the two following courses:	-----
		15-110 Principles of Computing	
		15-112 Fundamentals of Programming and Computer Science	

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
36-401 Modern Regression	36-402 Advanced Methods for Data Analysis	36-46x Special Topics	36-410 Introduction to Probability Modeling
Math Track Elective	36-3xx or 36-4xx Advanced Data Analysis Elective	21-355 Principles of Real Analysis I	Math Track Elective
-----	-----	-----	-----
-----	-----	-----	-----

Schedule 2

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
36-200 Reasoning with Data	21-122 Integration and Approximation	36-235 Probability and Statistical Inference I	36-236 Probability and Statistical Inference II
21-120 Differential and Integral Calculus	21-256 Multivariate Analysis	21-127 Concepts of Mathematics	21-241 Matrices and Linear Transformations
-----	One of the two following courses:	-----	-----
-----	15-110 Principles of Computing	-----	36-3xx or 36-4xx Advanced Data Analysis Elective
	15-112 Fundamentals of Programming and Computer Science		

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
36-350 Statistical Computing	36-402 Advanced Methods for Data Analysis	36-46x Special Topics	36-410 Introduction to Probability Modeling
36-401 Modern Regression	36-3xx or 36-4xx Advanced Data Analysis Elective	21-355 Principles of Real Analysis I	Math Track Elective
Math Track Elective	-----	-----	-----
-----	-----	-----	-----

B.S. in Statistics (Statistics and Neuroscience Track)

Peter Freeman, *Undergraduate Program Director*

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Students in the Bachelor of Science in Statistics (Statistics and Neuroscience Track) program develop and master a wide array of skills in computing, mathematics, statistical theory, and the interpretation and display of complex data. In addition, Statistics majors gain experience in applying statistical tools to real problems in other fields and learn the nuances of interdisciplinary collaboration. The requirements for the B.S. in Statistics (Neuroscience Track) are detailed below and are organized by categories #1-#7.

Curriculum

1. Mathematical Foundations (Prerequisites) 29–42 units

Mathematics is the language in which statistical models are described and analyzed, so some experience with basic calculus and linear algebra is an important component for anyone pursuing a program of study in Statistics & Data Science.

Calculus*

Complete one of the two following sequences of mathematics courses at Carnegie Mellon, each of which provides sufficient preparation in calculus:

Sequence 1

21-111	Calculus I	10
21-112	Calculus II	10
And one of the following three courses:		
21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	10
21-268	Multidimensional Calculus	11

Sequence 2

21-120	Differential and Integral Calculus	10
And one of the following three courses:		
21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	10
21-268	Multidimensional Calculus	11

Notes:

- Passing the Mathematical Sciences 21-120 assessment test is an acceptable alternative to completing 21-120.

Linear Algebra**

Complete *one* of the following three courses:

21-240	Matrix Algebra with Applications	10
21-241	Matrices and Linear Transformations	11
21-242	Matrix Theory	11

* It is recommended that students complete the calculus requirement during their freshman year.

**The linear algebra requirement needs to be completed before taking 36-401 Modern Regression.

21-241 and 21-242 are intended only for students with a very strong mathematical background.

2. Data Analysis 36-45 units

Data analysis is the art and science of extracting insight from data. The art lies in knowing which displays or techniques will reveal the most interesting features of a complicated data set. The science lies in understanding the various techniques and the assumptions on which they rely. Both aspects require practice to master.

The Beginning Data Analysis courses give a hands-on introduction to the art and science of data analysis. The courses cover similar topics but differ slightly in the examples they emphasize. 36-200 draws examples from many fields and satisfies the Dietrich College Core Requirement in Statistical Reasoning. This course is therefore recommended for students in the college. (Note: a score of 5 on the Advanced Placement [AP] Exam in Statistics may be used to waive this requirement). 36-220 emphasizes examples in engineering and architecture.

The Intermediate Data Analysis courses build on the principles and methods covered in the introductory course, and more fully explore specific types of data analysis methods in more depth.

The Advanced Data Analysis courses draw on students' previous experience with data analysis and understanding of statistical theory to develop advanced, more sophisticated methods. These core courses involve extensive analysis of real data with emphasis on developing the oral and writing skills needed for communicating results.

Sequence 1 (For students beginning their freshman or sophomore year)

Beginning*

Choose *one* of the following courses:

36-200	Reasoning with Data *	9
36-220	Engineering Statistics and Quality Control	9

*A score of 5 on the Advanced Placement (AP) Exam in Statistics may be used to waive this requirement. 36-220 emphasizes examples in engineering and Architecture.

Note: Students who enter the program with 36-235 or 36-236 should discuss options with an advisor.

Intermediate*

Choose *one* of the following courses:

36-202	Methods for Statistics & Data Science **	9
36-309	Experimental Design for Behavioral & Social Sciences	9
36-290	Introduction to Statistical Research Methodology	9
*Or an extra Advanced Data Analysis Elective		
** Must take prior to 36-401, if not, an additional Advanced Data Analysis Elective is required		

Advanced Data Analysis Electives

Choose *one* of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-313	Statistics of Inequality and Discrimination	9
36-315	Statistical Graphics and Visualization	9
36-318	Introduction to Causal Inference	9
36-460	Special Topics: Sports Analytics	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Statistical Machine Learning	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Psychometrics: A Statistical Modeling Approach	9
36-465	Special Topics: Conceptual Foundations of Statistical Learning	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-469	Special Topics: Statistical Genomics and High Dimensional Inference	9
36-470	Special Topics: Statistical Methods in Health Sciences	9
36-471	Special Topics: Time Series	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

Students can also take a second 36-46x (see section #5).

and take the following *two* courses:

36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9

Sequence 2 (For students beginning later in their college career)

Advanced Data Analysis Electives

Choose *two* of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-313	Statistics of Inequality and Discrimination	9
36-315	Statistical Graphics and Visualization	9
36-318	Introduction to Causal Inference	9
36-460	Special Topics: Sports Analytics	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Statistical Machine Learning	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Psychometrics: A Statistical Modeling Approach	9
36-465	Special Topics: Conceptual Foundations of Statistical Learning	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-469	Special Topics: Statistical Genomics and High Dimensional Inference	9
36-470	Special Topics: Statistical Methods in Health Sciences	9
36-471	Special Topics: Time Series	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

**All Special Topics are not offered every semester, and new Special Topics are regularly added. See section 5 for details.

and take the following *two* courses:

36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9

3. Probability Theory and Statistical Theory 18 units

The theory of probability gives a mathematical description of the randomness inherent in our observations. It is the language in which statistical models are stated, so an understanding of probability is essential for the study of statistical theory. Statistical theory provides a mathematical framework for making inferences about unknown quantities from data. The theory reduces statistical problems to their essential ingredients to help devise and evaluate inferential procedures. It provides a powerful and wide-ranging set of tools for dealing with uncertainty.

To satisfy the theory requirement take the following two courses:

Take one of the following courses:		
36-235	Probability and Statistical Inference I	9
36-225	Introduction to Probability Theory	9
and one of the following three courses:		
36-226	Introduction to Statistical Inference	9
36-236	Probability and Statistical Inference II **	9
36-326	Mathematical Statistics (Honors)	9

*It is possible to substitute 36-218, 36-219, 36-225, 15-259, or 21-325 for 36-235. 36-235 is the standard (and recommended) introduction to probability, 36-219 is tailored for engineers and computer scientists, 36-218 and 15-259 are more mathematically rigorous classes for Computer Science students and more mathematically advanced (students need advisor approval to enroll), and 21-325 is a rigorous probability theory course offered by the Department of Mathematics.

**It is possible to substitute 36-226 or 36-326 (honors course) in place of 36-236. 36-236 is the standard (and recommended) introduction to statistical inference.

Please note that students who complete 36-235 are expected to take 36-236 to complete their theory requirements. Students who choose to take 36-225 instead will be required to take 36-226 afterward. They will not be eligible to take 36-236.

Comment:

(i) In order to meet the prerequisite requirements, a grade of at least a C is required in 36-235 (or equivalent), 36-236 (or equivalent) and 36-401.

4. Statistical Computing 19 to 21 units

Fundamental to the practice of statistics and data science is the ability to effectively code data processing and analysis tasks. Within the domain of statistics, the use of the programming language R is ubiquitous, and thus we expose students to it throughout the curriculum (and in depth in Statistical Computing). Within the larger domain of data science, the use of the programming language Python is also ubiquitous, and thus we require all majors to gain, at a minimum, basic competency in the language by taking either Principles of Computing, or Fundamentals of Programming and Computer Science. We would advise those students who are considering receiving course credit for one of these two courses given their score on the AP Computer Science A exam to actually take one (or both) of them at Carnegie Mellon instead, as within data science as a whole Python is far more widely used than Java.

Take one of the two following courses:		
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
Complete the following course:		
36-350	Statistical Computing	9

5. Special Topics 9 units

The Department of Statistics & Data Science offers advanced courses that focus on specific statistical applications or advanced statistical methods. These courses are numbered 36-46x (36-461, 36-462, etc.) or 36-47x (36-470, 36-471, etc.). The objective of the course is to expose students to important topics in statistics and/or interesting applications which are not part of the standard undergraduate curriculum. Note that all Special Topics are not offered every semester, and new Special Topics are regularly added.

To satisfy the Special Topics requirement choose *one* of the **36-46x or 36-47x** courses (which are 9 units).

Note: All 36-46x and 36-47x courses require 36-401 as a prerequisite or corequisite.

6. Statistical Elective 9–12 units

Students are required to take one elective which can be within or outside the Department of Statistics & Data Science. **Courses within Statistics & Data Science** can be any 300 or 400 level course (that is not used to satisfy any other requirement for the statistics major).

The following is a partial list of **courses outside Statistics & Data Science** that qualify as electives as they provide the intellectual infrastructure that will advance the student's understanding of statistics and its applications. Other courses may qualify as well; consult with the Statistics Undergraduate Advisor.

15-121	Introduction to Data Structures	10
15-122	Principles of Imperative Computation	12
10-301	Introduction to Machine Learning	12
10-315	Introduction to Machine Learning (SCS Majors)	12
15-388	Practical Data Science	9
21-127	Concepts of Mathematics	12
21-260	Differential Equations	9
21-292	Operations Research I	9
21-301	Combinatorics	9
21-355	Principles of Real Analysis I	9
80-220	Philosophy of Science	9
80-221	Philosophy of Social Science	9
80-310	Formal Logic	9
85-310	Research Methods in Cognitive Psychology	9
85-320	Research Methods in Developmental Psychology	9
85-340	Research Methods in Social Psychology	9
88-223	Decision Analysis	12
88-302	Behavioral Decision Making	9

Statistics and Neuroscience Track 45–54 UNITS

85-211	Cognitive Psychology	9
85-219	Foundations of Brain and Behavior	9

And three electives (at least one from Methodology and Analysis and at least one within the Neuroscience Background listed below):

Methodology and Analysis

10-301	Introduction to Machine Learning	12
18-290	Signals and Systems	12
42-630	Introduction to Neural Engineering	12
42-632	Neural Signal Processing	12
36-700	Probability and Mathematical Statistics	12
42/86-631	Neural Data Analysis	12
85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9

Neuroscience Background

03-362	Cellular Neuroscience	9
03-363	Systems Neuroscience	9
15-386	Neural Computation	9
85-370	Perception	9
85-408	Visual Cognition	9
85-414	Cognitive Neuropsychology	9
85-419	Introduction to Parallel Distributed Processing	9

Total Number of Units for the Major:	**165-201* Units**
Total Number of Units for the Degree:	**360 Units**

*Note: This number can vary depending on the courses chosen for the concentration area that a student takes. Speak with an academic advisor for more details.

Recommendations

Students in the Dietrich College of Humanities and Social Sciences who wish to major or minor in Statistics are advised to complete both the calculus requirement (one Mathematical Foundations calculus sequence) and the Beginning Data Analysis course 36-200 by the end of their freshman year.

The linear algebra requirement is a prerequisite for the course 36-401. It is therefore essential that students complete this requirement by their junior years at the latest.

Recommendations for Prospective Ph.D. Students

Students interested in pursuing a Ph.D. in Statistics or Biostatistics (or related programs) after completing their undergraduate degree are strongly recommended to pursue the **Mathematical Statistics Track** or to take additional Mathematics courses. Although 21-240 Matrix Algebra with Applications is recommended for Statistics majors, students interested in PhD programs should consider taking 21-241 Matrices and Linear Transformations or 21-242 Matrix Theory instead. Additional courses to consider are 21-228 Discrete Mathematics, 21-341 Linear Algebra, 21-355 Principles of Real Analysis I, and 21-356 Principles of Real Analysis II.

Additional Major in Statistics (Neuroscience Track)

Students who elect the B.S. in Statistics (Neuroscience Track) as an additional major must fulfill all Statistics (Neuroscience Track) degree requirements. With respect to double-counting courses, it is departmental policy that students must have at least six courses [three Statistics courses (36-xxx) and three Neuroscience Track electives] that do not count for their primary major. If students do not have at least six, they typically take additional advanced data analysis and/or neuroscience electives.

Students are advised to begin planning their curriculum (with appropriate advisors) as soon as possible. This is particularly true if the other major has a complex set of requirements and prerequisites or when many of the other major's requirements overlap with the requirements for the B.S. in Statistics (Neuroscience Track).

Substitutions and Waivers

Many departments require Statistics & Data Science courses as part of their Major or Minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department of Statistics & Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics & Data Science. In many of these cases, the student will need to take additional courses to satisfy major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Statistics.

Research

The Statistics & Data Science program encourages students to gain research experience. Opportunities within the department include Summer Undergraduate Research Apprenticeships (SURA), run in association with the university's Office of Undergraduate Research and Scholar Development, and the departmental capstone courses 36-490 Undergraduate Research, , or 36-497 Corporate Capstone Project. (Note that these courses require an application.) Additionally, students can pursue independent study. For those students who maintain a quality point average of 3.25 overall or above, there is also the Dietrich College Senior Honors Program (p.).

The faculty in the Statistics & Data Science department largely work within the domains of statistical theory and methodological development, areas that require advanced mathematical training. Thus we encourage students to search broadly for research opportunities: faculty, post-doctoral researchers, and graduate students in many departments throughout the university have data to analyze and would welcome the help of undergraduate statistics students.

Sample Programs

The following sample programs illustrate three (of many) ways to satisfy the requirements for the B.S. in Statistics (Neuroscience Track). However, keep in mind that the program is flexible enough to support *many* other possible schedules and to emphasize a wide variety of interests.

The first schedule uses calculus sequence 2.

The second schedule is an example of the case when a student enters the program through 36-235 and 36-236 (and therefore skips the intermediate data analysis course). This schedule has more emphasis on statistical theory and probability.

schedule 1

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
36-200 Reasoning with Data	36-202 Methods for Statistics & Data Science	36-235 Probability and Statistical Inference I	36-236 Probability and Statistical Inference II
21-120 Differential and Integral Calculus	21-256 Multivariate Analysis	85-219 Foundations of Brain and Behavior	36-350 Statistical Computing
85-211 Cognitive Psychology	And one of the following two courses:	-----	21-240 Matrix Algebra with Applications
-----	15-110 Principles of Computing	-----	-----
	15-112 Fundamentals of Programming and Computer Science		

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
36-401 Modern Regression	36-402 Advanced Methods for Data Analysis	36-46x Special Topics	36-3xx or 36-4xx Advanced Data Analysis Elective
Neuroscience Track Elective	Neuroscience Track Elective	Neuroscience Track Elective	-----
-----	-----	-----	-----
-----	-----	-----	-----

Schedule 2

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
36-200 Reasoning with Data	36-202 Methods for Statistics & Data Science	21-256 Multivariate Analysis	21-240 Matrix Algebra with Applications
21-111 Calculus I	21-112 Calculus II	85-211 Cognitive Psychology	36-3xx or 36-4xx Advanced Data Analysis Elective
-----	Take one of the following two courses:	-----	-----
-----	15-110 Principles of Computing	-----	-----
	15-112 Fundamentals of Programming and Computer Science		

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
36-235 Probability and Statistical Inference I	36-236 Probability and Statistical Inference II	36-401 Modern Regression	36-402 Advanced Methods for Data Analysis
85-219 Foundations of Brain and Behavior	Neuroscience Track Elective	36-350 Statistical Computing	36-46x - Special Topics
-----		Neuroscience Track Elective	Neuroscience Track Elective
-----		36-3xx or 36-4xx Advanced Data Analysis Elective	-----

B.S. in Economics and Statistics

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Sylvie Aubin, *Academic Program Manager*

Location: Baker Hall 129
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The Major in Economics and Statistics provides an interdisciplinary course of study aimed at students with a strong interest in the empirical analysis of economic data. With a joint curriculum from the Department of Statistics and Data Science and the Undergraduate Economics Program, the major provides students with a solid foundation in the theories and methods of both fields. Students in this major are trained to advance the understanding of economic issues through the analysis, synthesis and reporting of data using the advanced empirical research methods of statistics and econometrics. Graduates are well positioned for admission to competitive graduate programs, including those in statistics, economics and management, as well as for employment in positions requiring strong analytical and conceptual skills - especially those in economics, finance, education, and public policy.

All economics courses counting towards an economics degree must be completed with a grade of "C" or higher.

Curriculum

The requirements for the B.S. in Economics and Statistics are the following:

1. MATHEMATICAL FOUNDATIONS (PREREQUISITES) 29-42 UNITS

Mathematics is the language in which statistical models are described and analyzed, so some experience with basic calculus and linear algebra is an important component for anyone pursuing a program of study in Economics and Statistics.

CALCULUS

Complete one of the two following sequences of mathematics courses at Carnegie Mellon, each of which provides sufficient preparation in calculus:

SEQUENCE 1

21-111	Calculus I	10
21-112	Calculus II	10

and *one* of the following:

21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	10
21-268	Multidimensional Calculus	11

SEQUENCE 2

21-120	Differential and Integral Calculus	10

and *one* of the following:

21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	10
21-268	Multidimensional Calculus	11

NOTES:

- Passing the Mathematical Sciences 21-120 assessment test is an acceptable alternative to completing 21-120.

Note: Taking/having credit for both 21-111 and 21-112 is equivalent to 21-120. The Mathematical Foundations total is then 48-49 units. The Economics and Statistics major would then total 201-211 units.

Linear Algebra

One of the following three courses:

21-240	Matrix Algebra with Applications	10
21-241	Matrices and Linear Transformations	11
21-242	Matrix Theory	11

Note: 21-241 and 21-242 are intended only for students with a very strong mathematical background.

II. Foundations 54 units

2. Economics Foundations 18 UNITS

Take one of the following courses:		
73-102	Principles of Microeconomics *	9
73-104	Principles of Microeconomics Accelerated **	9
Take the following course:		
73-103	Principles of Macroeconomics	9

*Students who place out of 73-102 based on the economics placement exam will receive a pre-req waiver for 73-102 and are waived from taking 73-102

**This course requires students to complete a 4 or 5 on the AP Microeconomics exam or qualifying score on the IB/Cambridge Exams. 73-104 will substitute for any 73-102 prerequisite requirement in other courses. 73-104 is a more rigorous introduction to microeconomics, is taught at a faster pace than 73-102, and dives a bit deeper into key topics. It is designed for students who have prior knowledge to fundamental economic concepts through AP/IB/ Cambridge coursework. Enrollment in 73-104 requires special permission. Students who wish to take this course should add themselves to the 73-104 waitlist once registration opens. The Tepper School will verify the advancement placement scores and will enroll students in 73-104

3. Statistical Foundations 36 UNITS

DATA ANALYSIS

Data analysis is the art and science of extracting insight from data. The art lies in knowing which displays or techniques will reveal the most interesting features of a complicated data set. The science lies in understanding the various techniques and the assumptions on which they rely. Both aspects require practice to master.

The Beginning Data Analysis courses give a hands-on introduction to the art and science of data analysis. The courses cover similar topics but differ slightly in the examples they emphasize. 36-200 draws examples from many fields and satisfy the Dietrich College Core Requirement in Statistical Reasoning. This course is therefore recommended for students in the college. (Note: a score of 5 on the Advanced Placement [AP] Exam in Statistics may be used to waive this requirement). 36-220 emphasizes examples in engineering.

The Intermediate Data Analysis courses build on the principles and methods covered in the introductory course, and more fully explore specific types of data analysis methods in more depth.

The Advanced Data Analysis courses draw on students' previous experience with data analysis and understanding of statistical theory to develop advanced, more sophisticated methods. These core courses involve extensive analysis of real data with emphasis on developing the oral and writing skills needed for communicating results.

Sequence 1 (For students beginning their freshman or sophomore year)

Beginning*

Choose *one* of the following courses:

36-200	Reasoning with Data *	9
36-220	Engineering Statistics and Quality Control	9

*A score of 5 on the Advanced Placement (AP) Exam in Statistics may be used to waive this requirement. 36-220 emphasizes examples in engineering and Architecture.

Note: Students who enter the program with 36-235 or 36-236 should discuss options with an advisor. Any 36-300 or 36-400 level course in Data Analysis that does not satisfy any other requirement for the Economics and Statistics Major may be counted as a Statistical Elective.

Intermediate*

Choose *one* of the following courses:

36-202	Methods for Statistics & Data Science **	9
36-290	Introduction to Statistical Research Methodology	9
36-309	Experimental Design for Behavioral & Social Sciences	9

* Or extra data analysis course in Statistics
** Must take prior to 36-401 Modern Regression, if not, an additional Advanced Statistics Elective is required.

Advanced Statistics Elective
Choose *two* of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-313	Statistics of Inequality and Discrimination	9
36-315	Statistical Graphics and Visualization	9
36-318	Introduction to Causal Inference	9
36-460	Special Topics: Sports Analytics	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Statistical Machine Learning	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Psychometrics: A Statistical Modeling Approach	9
36-465	Special Topics: Conceptual Foundations of Statistical Learning	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-469	Special Topics: Statistical Genomics and High Dimensional Inference	9
36-470	Special Topics: Statistical Methods in Health Sciences	9
36-471	Special Topics: Time Series	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

Sequence 2 (For students beginning later in their college career)

Advanced Statistics Electives
Choose *three* of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-313	Statistics of Inequality and Discrimination	9
36-315	Statistical Graphics and Visualization	9
36-318	Introduction to Causal Inference	9
36-460	Special Topics: Sports Analytics	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Statistical Machine Learning	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Psychometrics: A Statistical Modeling Approach	9
36-465	Special Topics: Conceptual Foundations of Statistical Learning	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-469	Special Topics: Statistical Genomics and High Dimensional Inference	9
36-470	Special Topics: Statistical Methods in Health Sciences	9
36-471	Special Topics: Time Series	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

**All Special Topics are not offered every semester, and new Special Topics are regularly added. See section 5 for details.

III. Disciplinary Core 136-139 units

1. Economics Core 27 UNITS

73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9
70-340	Business Communications	9

Economics Quantitative Analysis Requirements 27 UNITS

Course List		
73-265	Economics and Data Science	9
73-274	Econometrics I	9
Take one of the following courses:		
73-374	Econometrics II	9
73-423	Forecasting for Economics and Business	9
70-467	Machine Learning for Business Analytics	9

2. Statistics Core 36 UNITS

Take one of the following courses:		
36-235	Probability and Statistical Inference I *#	9
36-225	Introduction to Probability Theory	9
Take one of the following courses:		
36-236	Probability and Statistical Inference II **	9
36-226	Introduction to Statistical Inference	9
36-326	Mathematical Statistics (Honors)	9
Take both of the following courses:		
36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9

*In order meet the prerequisite requirements for the major, a grade of C or better is required in 36-235 (or equivalents), 36-236 or 36-326 and 36-401.

#It is possible to substitute 36-218, 36-219, 36-225, 15-259, or 21-325 for 36-235. 36-235 is the standard introduction to probability, 36-219 is tailored for engineers and computer scientists, 36-218 and 15-259 are more mathematically rigorous classes for Computer Science students and more mathematically advanced Statistics students (Statistics students need advisor approval to enroll), and 21-325 is a rigorous Probability Theory course offered by the Department of Mathematics.

**It is possible to substitute 36-226 or 36-326 for 36-236. 36-236 is the standard introduction to statistical inference.

Please note that students who complete 36-235 are expected to take 36-236 to fulfill their theory requirements. Students who choose to take 36-225 instead will be required to take 36-226 afterward, they will not be eligible to take 36-236.

3. Statistical Computing 19-21 UNITS

Take one of the following two courses:		
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
Complete the following course:		
36-350	Statistical Computing	9

4. Advanced Electives 36 units

Students must take two advanced Economics elective courses (numbered 73-300 through 73-495, excluding 73-374) and two (or three - depending on previous coursework, see Section 3) advanced Statistics elective courses (numbered 36-303, 36-311, 36-313, 36-315, 36-318, 36-46x, 36-490, or 36-497).

Total number of units for the major	**219-235 Units**
Total number of units for the degree	**360 Units**

Professional Development

While not required, students are strongly encouraged to take advantage of professional development opportunities and/or coursework. The Department of Statistics and Data Science also offers a series of workshops pertaining to resume preparation, graduate school applications, careers in the field, among other topics. Students should also take advantage of the Career and Professional Development Center.

Additional Major in Economics and Statistics

Students who elect Economics and Statistics as an additional major must fulfill all Economics and Statistics degree requirements. Majors in many other programs would naturally complement an Economics and Statistics Major, including Tepper's undergraduate business program, Social and Decision Sciences, Policy and Management, and Psychology.

With respect to double-counting courses, it is departmental policy that students must have at least six courses [three Economics (73-xxx) and three Statistics (36-xxx)] that do *not* count for their primary major. If students do not have at least three ECON and three STA classes, they will need to take additional advanced data analysis or economics electives, depending on where the double-counting issue is.

Students are advised to begin planning their curriculum (with appropriate advisors) as soon as possible. This is particularly true if the other major has a complex set of requirements and prerequisites or when many of the other major's requirements overlap with the requirements for a Major in Economics and Statistics.

Substitutions and Waivers

Many departments require Statistics courses as part of their Major or Minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor. The final authority in such decisions rests there. The Department of Statistics and Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics and Data Science. In many of these cases, the student will need to take additional courses to satisfy the Economics and Statistics major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Economics and Statistics.

Sample Program

The following sample program illustrates one way to satisfy the requirements of the Economics and Statistics Major. Keep in mind that the program is flexible and can support other possible schedules (see footnotes below the schedule).

First-Year		**Second-Year**	
Fall	**Spring**	**Fall**	**Spring**
21-120 Differential and Integral Calculus	36-202 Methods for Statistics & Data Science	36-235 Probability and Statistical Inference I	36-236 Probability and Statistical Inference II
36-200 Reasoning with Data	21-256 Multivariate Analysis	73-230 Intermediate Microeconomics	21-240 Matrix Algebra with Applications
73-102 Principles of Microeconomics	73-103 Principles of Macroeconomics	73-265 Economics and Data Science	73-240 Intermediate Macroeconomics
15-110 Principles of Computing	-----	70-340 Business Communications	73-274 Econometrics I
	-----	-----	-----

Third-Year		**Fourth-Year**	
Fall	**Spring**	**Fall**	**Spring**
36-350 Statistical Computing	36-402 Advanced Methods for Data Analysis	36-3xx or 36-4xx Advanced Data Analysis Elective	36-3xx or 36-4xx Advanced Data Analysis Elective
36-401 Modern Regression	-----	Economics Elective	Economics Elective
Advanced Quantitative Analysis Course	-----	-----	-----
-----		-----	-----
-----		-----	-----

*In each semester, ----- represents other courses (not related to the major) which are needed in order to complete the 360 units that the degree requires.

Prospective PhD students are advised to add 21-127 fall of sophomore year, replace 21-240 with 21-241, add 21-260 in spring of junior year and 21-355 in fall of senior year.

B.S. in Statistics and Machine Learning

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Students in the Bachelor of Science in Statistics and Machine Learning program develop and master a wide array of skills in computing, mathematics, statistical theory, and the interpretation and display of complex data. In addition, Statistics and Machine Learning majors gain experience in applying statistical tools to real problems in other fields and learn the nuances of interdisciplinary collaboration. This program is geared towards students interested in statistical computation, data science, or “Big Data” problems. The requirements for the B.S. in Statistics and Machine Learning are detailed below and are organized by categories.

Curriculum

1. Mathematical Foundations (Prerequisites) 41–54 units

Mathematics is the language in which statistical models are described and analyzed, so some experience with basic calculus and linear algebra is an important component for anyone pursuing a program of study in Statistics and Machine Learning.

Calculus*

Complete one of the following sequences of mathematics courses at Carnegie Mellon, each of which provides sufficient preparation in calculus:

Sequence 1

21-111	Calculus I	10
21-112	Calculus II	10

and *one* of the following:

21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	10
21-268	Multidimensional Calculus	11

Sequence 2

21-120	Differential and Integral Calculus	10

and *one* of the following:

21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	10
21-268	Multidimensional Calculus	11

Notes:

- Passing the Mathematical Sciences 21-120 assessment test is an acceptable alternative to completing 21-120

Linear Algebra**

Complete *one* of the following three courses:

21-240	Matrix Algebra with Applications	10
21-241	Matrices and Linear Transformations	11
21-242	Matrix Theory	11

* It is recommended that students complete the calculus requirement during their freshman year.

**The linear algebra requirement needs to be completed before taking 36-401 Modern Regression.

21-241 and 21-242 are intended only for students with a very strong mathematical background.

Mathematical Theory

21-127	Concepts of Mathematics	12

2. Data Analysis 45–54 units

Data analysis is the art and science of extracting insight from data. The art lies in knowing which displays or techniques will reveal the most interesting features of a complicated data set. The science lies in understanding the various techniques and the assumptions on which they rely. Both aspects require practice to master.

The Beginning Data Analysis courses give a hands-on introduction to the art and science of data analysis. The courses cover similar topics but differ slightly in the examples they emphasize. 36-200 draws examples from many fields and satisfies the Dietrich College Core Requirement in Statistical Reasoning. This course is therefore recommended for students in the college. (Note: a score of 5 on the Advanced Placement [AP] Exam in Statistics may be used to waive this requirement). 36-220 emphasizes examples in engineering and architecture.

The Intermediate Data Analysis courses build on the principles and methods covered in the introductory course, and more fully explore specific types of data analysis methods in more depth.

The Advanced Data Analysis courses draw on students' previous experience with data analysis and understanding of statistical theory to develop advanced, more sophisticated methods. These core courses involve extensive analysis of real data with emphasis on developing the oral and writing skills needed for communicating results.

Sequence 1 (For students beginning their freshman or sophomore year)

Beginning*

Choose one of the following courses:

36-200	Reasoning with Data *	9
36-220	Engineering Statistics and Quality Control	9

*A score of 5 on the Advanced Placement (AP) Exam in Statistics may be used to waive this requirement. 36-220 emphasizes examples in engineering and Architecture.

Note: Students who enter the program with 36-235 or 36-236 should discuss options with an advisor.

Intermediate*

Choose *one* of the following courses:

36-202	Methods for Statistics & Data Science **	9
36-309	Experimental Design for Behavioral & Social Sciences	9
36-290	Introduction to Statistical Research Methodology	9
*Or an extra Advanced Data Analysis Elective		
**Must take prior to 36-401 or will need to take an additional Advanced Data Analysis Elective		

Advanced Data Analysis Electives

Choose _two_ of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-313	Statistics of Inequality and Discrimination	9
36-315	Statistical Graphics and Visualization	9
36-318	Introduction to Causal Inference	9
36-460	Special Topics: Sports Analytics	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Statistical Machine Learning	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Psychometrics: A Statistical Modeling Approach	9
36-465	Special Topics: Conceptual Foundations of Statistical Learning	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-469	Special Topics: Statistical Genomics and High Dimensional Inference	9
36-470	Special Topics: Statistical Methods in Health Sciences	9
36-471	Special Topics: Time Series	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

All Special Topics are not offered every semester. They are on a rotation and new Special Topics are regularly added.

and take the following *two* courses:

36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9

Sequence 2 (For students beginning later in their college career)

Advanced Data Analysis Electives

Choose _three_ of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-313	Statistics of Inequality and Discrimination	9
36-315	Statistical Graphics and Visualization	9
36-318	Introduction to Causal Inference	9
36-460	Special Topics: Sports Analytics	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Statistical Machine Learning	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Psychometrics: A Statistical Modeling Approach	9

36-465	Special Topics: Conceptual Foundations of Statistical Learning	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-469	Special Topics: Statistical Genomics and High Dimensional Inference	9
36-470	Special Topics: Statistical Methods in Health Sciences	9
36-471	Special Topics: Time Series	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

All Special Topics are not offered every semester. They are on a rotation and new Special Topics are regularly added.

and take the following *two* courses:

36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9

3. Probability Theory and Statistical Theory 18 units

The theory of probability gives a mathematical description of the randomness inherent in our observations. It is the language in which statistical models are stated, so an understanding of probability is essential for the study of statistical theory. Statistical theory provides a mathematical framework for making inferences about unknown quantities from data. The theory reduces statistical problems to their essential ingredients to help devise and evaluate inferential procedures. It provides a powerful and wide-ranging set of tools for dealing with uncertainty.

To satisfy the theory requirement take the following *two* courses**:

Take one of the following courses:		
36-235	Probability and Statistical Inference I *	9
36-225	Introduction to Probability Theory	9
And one of the three following courses:		
36-226	Introduction to Statistical Inference	9
36-236	Probability and Statistical Inference II **	9
36-326	Mathematical Statistics (Honors)	9

*It is possible to substitute 36-218, 36-219, 36-225, 15-259, or 21-325 for 36-235 . 36-235 is the standard (and recommended) introduction to probability, 36-219 is tailored for engineers and computer scientists, 36-218 and 15-259 are more mathematically rigorous classes for Computer Science students and more mathematically advanced (students need advisor approval to enroll), and 21-325 is a rigorous probability theory course offered by the Department of Mathematics.)

**It is possible to substitute 36-226 or 36-326(honors course) for 36-236. 36-236 is the standard (and recommended) introduction to statistical inference.

Please note that students who complete 36-235 are expected to take 36-236 to complete their theory requirements. Students who choose to take 36-225 instead will be required to take 36-226 afterward. They will not be eligible to take 36-236.

Comments:

(i) In order to meet the prerequisite requirements, a grade of at least a C is required in 36-235 (or equivalent), 36-236 (or equivalent) and 36-401.

4. Statistical Computing 9 units

Fundamental to the practice of statistics and data science is the ability to effectively code data processing and analysis tasks. Within the domain of statistics, the use of the programming language R is ubiquitous, and thus we expose students to it throughout the curriculum (and in depth in Statistical Computing).

36-350	Statistical Computing	9

5. Machine Learning/Computer Science 57-60 units

Statistical modeling in practice nearly always requires computation in one way or another. Computational algorithms are sometimes treated as “black boxes," whose innards the statistician need not pay attention to. But this attitude is becoming less and less prevalent, and today there is much to be gained from a strong working knowledge of computational tools. Understanding the strengths and weaknesses of various methods allows the data analyst to select the right tool for the job; understanding how they can be adapted to work in new settings greatly extends the realm of problems that he/she can solve. While all majors in Statistics & Data Science are given solid grounding in computation, extensive computational training is really what sets the B.S. in Statistics and Machine Learning program apart. Note that we would advise those students who are considering receiving course credit for Fundamentals of Programming and Computer Science given their score on the AP Computer Science A exam to actually take the course at Carnegie Mellon instead, as within data science as a whole Python is far more widely used than Java.

15-112	Fundamentals of Programming and Computer Science	12
15-122	Principles of Imperative Computation	12
15-351	Algorithms and Advanced Data Structures	12
or 15-451	Algorithm Design and Analysis	
10-301	Introduction to Machine Learning	12
or 10-315	Introduction to Machine Learning (SCS Majors)	

and take *one* of the following Machine Learning Advanced Electives:

05-434	Machine Learning in Practice	12
10-403	Deep Reinforcement Learning & Control	12
10-703	Deep Reinforcement Learning & Control	12
10-405	Machine Learning with Large Datasets (Undergraduate)	12
10-605	Machine Learning with Large Datasets	12
10-417	Intermediate Deep Learning	12
10-418	Machine Learning for Structured Data	12
10-707	Advanced Deep Learning	12
11-344	Machine Learning in Practice	12
11-411	Natural Language Processing	12
11-441	Machine Learning with Graphs	9
11-485	Introduction to Deep Learning	9
11-661	Language and Statistics	12
11-761	Language and Statistics	12
15-281	Artificial Intelligence: Representation and Problem Solving	12
15-386	Neural Computation	9
15-387	Computational Perception	9
16-311	Introduction to Robotics	12
16-385	Computer Vision	12
16-720	Computer Vision	12
*PhD level ML course as approved by Statistics advisor		
** Independent research with an ML faculty member as approved by Statistics Advisor		
***This is not an exhaustive list. Please contact your Academic Advisor if there is a course you are considering taking that is not on this list.		

Total number of units for the major	**170-195 Units**
Total number of units for the degree	**360 Units**

Recommendations

Students in the Dietrich College of Humanities and Social Sciences who wish to declare a Statistics and Machine Learning major are advised to complete both the calculus requirement (one Mathematical Foundations calculus sequence) and the Beginning Data Analysis course 36-200 Reasoning with Data by the end of their Freshman year.

The linear algebra requirement is a prerequisite for the course 36-401 . It is therefore essential that students complete this requirement by their junior years at the latest.

Recommendations for Prospective Ph.D. Students

Students interested in pursuing a Ph.D. in Statistics or Machine Learning (or related programs) after completing their undergraduate degree are strongly recommended to take additional Mathematics courses. Although 21-240 Matrix Algebra with Applications is recommended for Statistics majors, students interested in PhD programs should consider taking 21-241 Matrices and Linear Transformations or 21-242 Matrix Theory instead. Additional courses to consider are 21-228 Discrete Mathematics, 21-341

Linear Algebra, 21-355 Principles of Real Analysis I, and 21-356 Principles of Real Analysis II.

Additional experience in programming and computational modeling is also recommended. Students should consider taking more than one course from the list of Machine Learning electives provided under the Computing section.

Additional Major in Statistics and Machine Learning

Students who elect Statistics and Machine Learning as a second or third major must fulfill *all* degree requirements.

With respect to double-counting courses, it is departmental policy that students must have at least six courses (three Computer Science/Machine Learning and three Statistics) that do *not* count for their primary major. If students do not have at least six, they will need to take additional advanced data analysis or ML electives, depending on where the double counting issue is.

Students are advised to begin planning their curriculum (with appropriate advisors) as soon as possible. This is particularly true if the other major has a complex set of requirements and prerequisites or when many of the other major's requirements overlap with the requirements for the B.S. in Statistics and Machine Learning.

Substitutions and Waivers

Many departments require Statistics & Data Science courses as part of their Major or Minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department of Statistics & Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics & Data Science. In many of these cases, the student will need to take additional courses to satisfy major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Statistics and Machine Learning.

Research

The Statistics & Data Science program encourages students to gain research experience. Opportunities within the department include Summer Undergraduate Research Apprenticeships (SURA), run in association with the university's Office of Undergraduate Research and Scholar Development, and the departmental capstone courses 36-490 Undergraduate Research or 36-497 Corporate Capstone Project. (Note that these courses require an application.) Additionally, students can pursue independent study. For those students who maintain a quality point average of 3.25 overall or above, there is also the Dietrich College Senior Honors Program (p.).

The faculty in the Statistics & Data Science department largely work within the domains of statistical theory and methodological development, areas that require advanced mathematical training. Thus we encourage students to search broadly for research opportunities: faculty, post-doctoral researchers, and graduate students in many departments throughout the university have data to analyze and would welcome the help of undergraduate statistics students.

Sample Programs

The following sample program illustrates one way to satisfy the requirements for the B.S. in Statistics and Machine Learning. Keep in mind that the program is flexible and can support other possible schedules (see footnotes below the schedule). Sample program 1 is for students who have not satisfied the basic calculus requirements. Sample program 2 is for students who have satisfied the basic calculus requirements and choose option 2 for their data analysis courses (see section #2)

Schedule 1

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
36-200 Reasoning with Data	36-202 Methods for Statistics & Data Science	36-235 Probability and Statistical Inference I	36-236 Probability and Statistical Inference II
21-120 Differential and Integral Calculus	21-256 Multivariate Analysis	21-127 Concepts of Mathematics	21-241 Matrices and Linear Transformations
-----	15-112 Fundamentals of Programming and Computer Science	-----	15-122 Principles of Imperative Computation
-----	-----	-----	36-350 Statistical Computing
-----	-----		-----

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
36-401 Modern Regression	36-402 Advanced Methods for Data Analysis	10-301 Introduction to Machine Learning	Machine Learning Advanced Elective
-----	15-351 Algorithms and Advanced Data Structures	36-3xx or 36-4xx Advanced Data Analysis Elective	36-3xx or 36-4xx Advanced Data Analysis Elective
-----	-----	-----	-----
-----	-----	-----	-----
-----	-----	-----	-----

*In each semester, ----- represents other courses (not related to the major) which are needed in order to complete the 360 units that the degree requires.

Schedule 2

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
36-200 Reasoning with Data	21-127 Concepts of Mathematics	36-235 Probability and Statistical Inference I	36-236 Probability and Statistical Inference II
21-256 Multivariate Analysis	-----	15-122 Principles of Imperative Computation	21-241 Matrices and Linear Transformations
15-112 Fundamentals of Programming and Computer Science	-----	-----	36-3xx or 36-4xx Advanced Data Analysis Elective
-----	-----	-----	-----
-----	-----	-----	-----

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
36-350 Statistical Computing	36-402 Advanced Methods for Data Analysis	10-301 Introduction to Machine Learning	Machine Learning Advanced Elective
36-401 Modern Regression	15-351 Algorithms and Advanced Data Structures	36-3xx or 36-4xx Advanced Data Analysis Elective	36-3xx or 36-4xx Advanced Data Analysis Elective
-----	-----	-----	-----
-----	-----	-----	-----
-----	-----	-----	-----

*In each semester, "-----" represents other courses (not related to the major) which are needed in order to complete the 360 units that the degree requires.

The Minor in Statistics

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The Minor in Statistics develops skills that complement major study in other disciplines. The program helps the student master the basics of statistical theory and advanced techniques in data analysis. This is a good choice for deepening understanding of statistical ideas and for strengthening research skills.

In order to complete a minor in Statistics a student must satisfy all of the following requirements:

1. Mathematical Foundations (Prerequisites) 29-41 units

Calculus:*:

Complete *one* of the following two sequences of mathematics courses at Carnegie Mellon, each of which provides sufficient preparation in calculus:

Sequence 1

21-111	Calculus I	10
21-112	Calculus II	10

and *one* of the following:

21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	10
21-268	Multidimensional Calculus	11

Sequence 2

21-120	Differential and Integral Calculus	10

and *one* of the following:

21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	10
21-268	Multidimensional Calculus	11

Note: Passing the Mathematical Sciences 21-120 assessment test if an acceptable alternative to completing 21-120.

Linear Algebra:

Complete *one* of the following three courses:

21-240	Matrix Algebra with Applications	10
21-241	Matrices and Linear Transformations	11
21-242	Matrix Theory	11

*It is recommended that students complete the calculus requirement during their freshman year.

**The linear algebra requirement needs to be complete before taking 36-401 Modern Regression or 36-46X or 36-47X Special Topics.

21-241 and 21-242 are intended only for students with a very strong mathematical background.

2. Data Analysis 36 units

Data analysis is the art and science of extracting insight from data. The art lies in knowing which displays or techniques will reveal the most interesting features of a complicated data set. The science lies in understanding the various techniques and the assumptions on which they rely. Both aspects require practice to master.

The Beginning Data Analysis courses give a hands-on introduction to the art and science of data analysis. The courses cover similar topics but differ slightly in the examples they emphasize. 36-200 draws examples from many fields and satisfies the Dietrich College Core Requirement in Statistical Reasoning. This course is therefore recommended for students in the College. (Note: A score of 5 on the Advanced Placement (AP) Exam in Statistics may be used to waive this requirement). 36-220 is another course that can complete the Beginning Data Analysis requirement that emphasizes examples in engineering and architecture.

The Intermediate Data Analysis courses build on the principles and methods covered in the introductory course, and more fully explore specific types of data analysis methods in more depth.

The Advanced Data Analysis and Methodology courses draw on students' previous experience with data analysis and understanding of statistical theory to develop advanced, more sophisticated methods. These core courses involve extensive analysis of real data with emphasis on developing the oral and writing skills needed for communicating results.

<u>Sequence 1 (For students beginning their freshman or sophomore year)</u>

Beginning Data Analysis*

Choose *one* of the following courses:

36-200	Reasoning with Data *	9
36-220	Engineering Statistics and Quality Control	9

*A score of 5 on the Advanced Placement (AP) Exam in Statistics may be used to waive this requirement. 36-220 emphasizes examples in engineering and Architecture.

Intermediate Data Analysis*

Choose *one* of the following courses:

36-202	Methods for Statistics & Data Science **	9
36-290	Introduction to Statistical Research Methodology	9
36-309	Experimental Design for Behavioral & Social Sciences	9

*The Beginning and Intermediate Data Analysis sequence (i.e. 36-200 and 36-202, or equivalents as listed above) can be replaced with an *additional* Advanced Analysis and Methodology course, shown below in Sequence 2.

**Must take the Intermediate Data Analysis requirement prior to 36-401, if not, an additional Advanced Analysis and Methodology course is required.

Advanced Data Analysis and Methodology

Take the following course:

36-401	Modern Regression	9

and <u>*one*</u> of the following courses:

36-402	Advanced Methods for Data Analysis	9
36-410	Introduction to Probability Modeling	9
36-460	Special Topics: Sports Analytics	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Statistical Machine Learning	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Psychometrics: A Statistical Modeling Approach	9
36-465	Special Topics: Conceptual Foundations of Statistical Learning	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-469	Special Topics: Statistical Genomics and High Dimensional Inference	9
36-470	Special Topics: Statistical Methods in Health Sciences	9
36-471	Special Topics: Time Series	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

Special Topics rotate and new ones are regularly added.

<u>Sequence 2 (For students beginning later in their college career)</u>

Advanced Data Analysis and Methodology

Take the following course:

36-401	Modern Regression	9

and take <u>*two*</u> of the following courses (one of which must be 400-level):

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-313	Statistics of Inequality and Discrimination	9
36-315	Statistical Graphics and Visualization	9
36-318	Introduction to Causal Inference	9
36-402	Advanced Methods for Data Analysis	9
36-410	Introduction to Probability Modeling	9
36-460	Special Topics: Sports Analytics	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Statistical Machine Learning	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Psychometrics: A Statistical Modeling Approach	9
36-465	Special Topics: Conceptual Foundations of Statistical Learning	9
36-466	Special Topics: Statistical Methods in Finance	9

36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-469	Special Topics: Statistical Genomics and High Dimensional Inference	9
36-470	Special Topics: Statistical Methods in Health Sciences	9
36-471	Special Topics: Time Series	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

Special Topics rotate and new ones are regularly added.

3. Probability Theory and Statistical Theory 18 units

The theory of probability gives a mathematical description of the randomness inherent in our observations. It is the language in which statistical models are stated, so an understanding of probability is essential for the study of statistical theory. Statistical theory provides a mathematical framework for making inferences about unknown quantities from data. The theory reduces statistical problems to their essential ingredients to help devise and evaluate inferential procedures. It provides a powerful and wide-ranging set of tools for dealing with uncertainty.

To satisfy the theory requirement take the following *two* courses:

Take one of the following courses:		
36-235	Probability and Statistical Inference I *	9
36-225	Introduction to Probability Theory	9
And one of the following three courses:		
36-236	Probability and Statistical Inference II **	9
36-226	Introduction to Statistical Inference	9
36-326	Mathematical Statistics (Honors)	9

*It is possible to substitute 36-218, 36-219 , 36-225, 15-259, or 21-325 for 36-235 . (36-235 is the standard (and recommended) introduction to probability, 36-219 is tailored for engineers and computer scientists, 36-218 and 15-259 are more mathematically rigorous classes for Computer Science students and more mathematically advanced (students need advisor approval to enroll), and 21-325 is a rigorous Probability Theory course offered by the Department of Mathematics.) 36-326 is not offered every semester/year but can be substituted for 36-226 and is considered an honors course.

**It is possible to substitute 36-226 or 36-326 (honors course) for 36-236. 36-236 is the standard (and recommended) introduction to statistical inference.

Please note that students who complete 36-235 are expected to take 36-236 to fulfill their theory requirements. Students who choose to take 36-225 instead will be required to take 36-226 afterward, they will not be eligible to take 36-236.

Comments:

(i) In order to be in good standing and to continue with the minor, a grade of at least a C is required in 36-235 (or equivalent), and 36-236 (or equivalent).

Total number of units required for the minor	**83 Units**

Double Counting

With respect to double-counting courses, it is departmental policy that students must have at least three statistics courses (36-xxx) that do *not* count for their primary major. If students do not have at least three, they need to take additional advanced electives. Make sure to consult your Statistics Minor advisor regarding double counting.

Sample Programs for the Minor

The following two sample programs illustrates two (of many) ways to satisfy the requirements of the Statistics Minor. Keep in mind that the program is flexible and can support many other possible schedules.

The first schedule uses calculus sequence 1, 36-200, and 36-202 to satisfy the intermediate data analysis requirement. The second schedule is an example of the case when a student enters the Minor through 36-235 and 36-236 (and therefore skips the beginning data analysis course). The schedule uses calculus sequence 2, and an advanced data analysis elective (to replace the beginning data analysis course).

Schedule 1

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
21-111 Calculus I	21-112 Calculus II	36-202 Methods for Statistics & Data Science	21-240 Matrix Algebra with Applications
36-200 Reasoning with Data		21-256 Multivariate Analysis	

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
36-235 Probability and Statistical Inference I	36-236 Probability and Statistical Inference II	36-401 Modern Regression	Any 36-4xx level course

Schedule 2

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
21-120 Differential and Integral Calculus	21-256 Multivariate Analysis	36-235 Probability and Statistical Inference I	36-236 Probability and Statistical Inference II
			21-240 Matrix Algebra with Applications

Third-Year		Fourth-Year
Fall	**Spring**	**Fall**
36-401 Modern Regression	36-3xx or 36-4xx Advanced Data Analysis Elective	One 36-4xx Advanced Methodology Course

Statistics & Data Science Dietrich Senior Honors Thesis

Eligibility

Eligibility is determined by Dietrich College. Students who are eligible will be notified prior to their senior year.

Dietrich College Requirements (https://www.cmu.edu/dietrich/students/undergraduate/programs/senior-honors/):

- Students *must have a major in Dietrich College*, either as a primary or an additional major; or be in the BHA (https://www.cmu.edu/interdisciplinary/programs/bha.html) program.
- Cumulative QPA through the end of the junior year of at least 3.25 overall, and 3.50 in the Dietrich College major associated with the proposed project.
- Departmental sponsorship in the form of an agreement by a faculty member to serve as advisor for the 2-semester/18 unit Honors project (graduate students may not serve as advisors; adjunct faculty may do so, but only in collaboration with a regular faculty member), and approval by the department head.

Statistics & Data Science Requirements Overview

The below guidelines apply to any Statistics & Data Science students who are doing an honors thesis that has been *approved through the Statistics & Data Science department* (i.e. our department signs off on the thesis paperwork). If you are a Stat & DS student pursuing a Dietrich senior honors thesis through another department (i.e. a different department than Stat & DS is signing off on it) then these guidelines do not apply to you.

In order to be approved for a thesis with the Stat & DS department the project needs to have a significant statistical component. This will be discussed and confirmed during the proposal approval phase of applying.

Honors Thesis Timeline

Senior Year - Fall Semester

The Dietrich College senior honors thesis is a year-long project. As such, after the fall semester of a student's senior year a progress report will be due to Undergraduate Program Director, Peter Freeman (pfreeman@andrew.cmu.edu), for review.

Progress Paper Requirements:

- Minimum length - 5 pages of text (not including graphs/figures/ results)
- This paper should build substantially on the proposal, and lay out what work has been done up to this point, as well as an action plan for the spring semester.
- Must be sent to Undergraduate Program Director, Peter Freeman (pfreeman@andrew.cmu.edu), by the last day of classes for the fall semester (typically the first week of December).

Senior Year - Spring Semester

Final Thesis Requirements:

In alignment with a typical advanced data analysis (ADA) project in the field of Statistics the minimum required length of the final thesis must be a minimum of 15 written pages, no more than 18 single-spaced pages, 12-point font. *This does *not* include figures.*

- Figures can be embedded within the text (so long as the overall text length requirement is met) but can also be provided as appendices after the main body of the text.
- Reports should be written in IMRaD format (Introduction, Methods, Results, and Discussion), where the "Introduction" can be a Background and Significance section followed by a Data section.
- All theses are due to the Undergraduate Program Director, Peter Freeman (pfreeman@andrew.cmu.edu), and Department Head, Rebecca Nugent (rnugent@andrew.cmu.edu), at the end of the 12th week of class in spring semester (roughly the first week of April).

Substitutions and Waivers

Many departments require Statistics & Data Science courses as part of their major or minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department of Statistics & Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

However, the Statistics & Data Science department's Director of Undergraduate Studies can provide advice and information to the student's advisor about the viability of a proposed substitution. Students should make available as much information as possible concerning proposed substitutions. Students seeking waivers may be asked to demonstrate mastery of the material.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics & Data Science. In many of these cases, the student will need to take additional courses to satisfy the Statistics major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Statistics.

Statistics majors and minors seeking substitutions or waivers should speak to a departmental academic advisor.

Faculty

SIVARAMAN BALAKRISHNAN, Associate Professor – Ph.D., Carnegie Mellon; Carnegie Mellon, 2015–

ELI BEN-MICHAEL, Assistant Professor, Joint With Heinz College – Ph.D., University of California; Carnegie Mellon, 2022–

ZACHARY BRANSON, Assistant Teaching Professor – Ph.D., Harvard University; Carnegie Mellon, 2019–

DAVID CHOI, Associate Professor of Statistics and Information Systems – Ph.D., Stanford University; Carnegie Mellon, 2004–

ALEXANDRA CHOULDECHOVA, Estella Loomis McCandless Assistant Professor of Statistics and Public Policy – Ph.D. , Stanford University; Carnegie Mellon, 2014–

REBECCA DOERGE, Dean of Mellon College of Science, Professor of Statistics – Ph.D., North Carolina State University; Carnegie Mellon, 2016–

PETER E. FREEMAN, Associate Teaching Professor; Director of Undergraduate Studies – Ph.D. , University of Chicago; Carnegie Mellon, 2004–

CHRISTOPHER R. GENOVESE, Professor – Ph.D., University of California; Carnegie Mellon, 1994–

JOEL B. GREENHOUSE, Professor – Ph.D., University of Michigan; Carnegie Mellon, 1982–

AMELIA HAVILAND, Anna Loomis McCandless Professor of Statistics and Public Policy – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2003–

JIASHUN JIN, Professor – Ph.D., Stanford University; Carnegie Mellon, 2007–

ROBERT E. KASS, Maurice Falk Professor of Statistics & Computational Neuroscience – Ph.D., University of Chicago; Carnegie Mellon, 1981–

EDWARD KENNEDY, Associate Professor – Ph.D., University of Pennsylvania; Carnegie Mellon, 2016–

ARUN KUCHIBHOTLA, Assistant Professor – Ph.D., University of Pennsylvania; Carnegie Mellon, 2020–

MIKAEL KUUSELA, Assistant Professor – Ph.D., Ecole Polytechnique Federale de Lausanne; Carnegie Mellon, 2018–

ANN LEE, Professor, Co-Director of PhD program – Ph.D., Brown University; Carnegie Mellon, 2005–

JING LEI, Professor – Ph.D., University of California; Carnegie Mellon, 2011–

ROBIN MEJIA, Assistant Research Professor – Ph.D., University of California; Carnegie Mellon, 2018–

GONZALO E. MENA, Assistant Professor – Ph.D., Columbia University; Carnegie Mellon, 2023–

DANIEL NAGIN, Teresa and H. John Heinz III Professor of Public Policy – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1976–

MATEY NEYKOV, Associate Professor – Ph.D., Harvard University; Carnegie Mellon, 2017–

NYNKE NIEZINK, Assistant Professor – Ph.D., University of Groningen; Carnegie Mellon, 2017–

REBECCA NUGENT, Department Head, Stephen E. and Joyce Fienberg Professor of Statistics & Data Science – Ph.D., University of Washington; Carnegie Mellon, 2006–

AADITYA RAMDAS, Assistant Professor – Ph.D., Carnegie Mellon; Carnegie Mellon, 2018–

ALEX REINHART, Assistant Teaching Faculty – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2018–

KATHRYN ROEDER, UPMC Professor of Statistics and Life Sciences – Ph.D., Pennsylvania State University; Carnegie Mellon, 1994–

CHAD M. SCHAFER, Professor – Ph.D., University of California, Berkeley; Carnegie Mellon, 2004–

TEDDY SEIDENFELD, Herbert A. Simon Professor of Philosophy and Statistics – Ph.D., Columbia University; Carnegie Mellon, 1985–

COSMA SHALIZI, Associate Professor – Ph.D., University of Wisconsin, Madison; Carnegie Mellon, 2005–

WEIJING TANG, Assistant Professor – Ph.D., University of Michigan; Carnegie Mellon, 2023–

WILL TOWNES, Assistant Professor – Ph.D., Harvard University; Carnegie Mellon, 2022–

VALERIE VENTURA, Professor, Co-Director of PhD program – Ph.D., University of Oxford; Carnegie Mellon, 1997–

ISABELLA VERDINELLI, Professor in Residence – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1991–

LARRY WASSERMAN, UPMC Professor of Statistics – Ph.D., University of Toronto; Carnegie Mellon, 1988–

RON YURKO, Assistant Teaching Professor – Ph.D., Carnegie Mellon; Carnegie Mellon, 2022–

Emeriti Faculty

GEORGE T. DUNCAN, Professor of Statistics and Public Policy – Ph.D., University of Minnesota; Carnegie Mellon, 1974–

WILLIAM F. EDDY, John C. Warner Professor of Statistics – Ph.D, Yale University; Carnegie Mellon, 1976–

BRIAN JUNKER, Professor – Ph.D., University of Illinois; Carnegie Mellon, 1990–

JOSEPH B. KADANE, Leonard J. Savage Professor of Statistics and Social Sciences – Ph.D., Stanford University; Carnegie Mellon, 1969–

JOHN P. LEHOCZKY, Thomas Lord Professor of Statistics – Ph.D, Stanford; Carnegie Mellon, 1969–

MARK J. SCHERVISH, Professor – Ph.D., University of Illinois; Carnegie Mellon, 1979–

DALENE STANGL, Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2017–

Special Faculty

PHILIPP BURCKHARDT, Director of e-Learning, Analytics, and Technology – Ph.D., Carnegie Mellon; Carnegie Mellon, 2022–

F. SPENCER KOERNER, Lecturer – Ph.D., Carnegie Mellon; Carnegie Mellon, 2022–

JAMIE MCGOVERN, Director: Master of Statistical Practice Program – B.A., Rice University; Carnegie Mellon, 2020–

GORDON WEINBERG, Senior Lecturer – M.A., University of Pittsburgh; Carnegie Mellon, 2004–

Affiliated Faculty

ANTHONY BROCKWELL – Ph.D., Melbourne University; Carnegie Mellon, 1999–

BERNIE DEVLIN – Ph.D., Pennsylvania State University; Carnegie Mellon, 1994–

TAEYONG PARK, Assistant Teaching Professor – Ph.D., Washington University in St. Louis; Carnegie Mellon, 2018–

ALESSANDRO RINALDO, Professor – Ph.D., Carnegie Mellon; Carnegie Mellon, 2005–

SAM VENTURA – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2015–

Department of Statistics and Data Science Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

36-198 Research Training: Writing in Statistics

Intermittent
TBD
Prerequisite: 36-200

36-200 Reasoning with Data

All Semesters: 9 units
This course is an introduction to learning how to make statistical decisions and now to reason with data. The approach will emphasize the thinking-through of empirical problems from beginning to end and using statistical tools to look for evidence for/against explicit arguments/hypotheses. Types of data will include continuous and categorical variables, images, text, networks, and repeated measures over time. Applications will largely drawn from interdisciplinary case studies spanning the humanities, social sciences, and related fields. Methodological topics will include basic exploratory data analysis, elementary probability, significance tests, and empirical research methods. There will be once-weekly computer lab for additional hands-on practice using an interactive software platform that allows student-driven inquiry.

36-202 Methods for Statistics & Data Science

All Semesters: 9 units
This course builds on the principles and methods of statistical reasoning developed in 36-200 (or its equivalents). The course covers simple and multiple regression, basic analysis of variance methods, logistic regression, and introduction to data mining including classification and clustering. Students will also learn the principles of overfitting, training vs testing, ensemble methods, variable selection, and bootstrapping. Course objectives include applying the basic principles and methods that underlie statistical practice and empirical research to real data sets and interdisciplinary problems. Learning the Data Analysis Pipeline is strongly emphasized through structured coding and data analysis projects. In addition to three lectures a week, students attend a computer lab once a week for "hands-on" practice of the material covered in lecture. There is no programming language pre-requisite. Students will learn the basics of R Markdown and related analytics tools.
Prerequisites: 36-200 or 36-220 or 36-247 or 36-207 or 70-207

36-204 Discovering the Data Universe

Intermittent: 3 units
Every day we wake up in the data universe, we use the information around us to make decisions. We are constantly evaluating and interpreting data from our environment, in everything from spreadsheets to Instagram posts. At the same time, our own personal data are being observed and recorded and #8212;through websites we visit online, our smart devices, and even our interactions with other students and faculty at CMU. Navigating this data universe requires knowledge of what data is and how to use it responsibly. For example, can a plant be a data set? Discovering the truth behind a piece of data, including who made it, what it looks like, and what we can learn from it, is a critical skill. Understanding data can be the difference between being able to distinguish truth from lies; and the key to identifying your data footprint and succeeding in research and in your career. In this course, we will explore the data universe from multiple angles and across several types of data. We will define, find, and analyze data, and most importantly, identify narratives within data to tell stories about the world around us. We will examine data using the following questions: How can we tell multiple stories from the same dataset? What biases can exist in data? And, who creates or decides what data matters enough to collect, preserve, and share? NOTE: There will be one in person and one virtual pre-recorded lecture each week.

36-218 Probability Theory for Computer Scientists

Fall and Spring: 9 units
Probability theory is the mathematical foundation for the study of both statistics and of random systems. This course is an intensive introduction to probability,from the foundations and mechanics to its application in statistical methods and modeling of random processes. Special topics and many examples are drawn from areas and problems that are of interest to computer scientists and that should prepare computer science students for the probabilistic and statistical ideas they encounter in downstream courses and research. A grade of C or better is required in order to use this course as a pre-requisite for 36-226, 36-326, and 36-410. If you hold a Statistics primary/additional major or minor you will be required to complete 36-226. For those who do not have a major or minor in Statistics, and receive at least a B in 36-218, you will be eligible to move directly onto 36-401.
Prerequisites: (21-111 and 21-112) or 21-120 or 21-256 or 21-259

Course Website: http://www.stat.cmu.edu/academics/courselist (http://www.stat.cmu.edu/academics/courselist/)

36-219 Probability Theory and Random Processes

All Semesters: 9 units
This course provides an introduction to probability theory. It is designed for students in electrical and computer engineering. Topics include elementary probability theory, conditional probability and independence, random variables, distribution functions, joint and conditional distributions, limit theorems, and an introduction to random processes. Some elementary ideas in spectral analysis and information theory will be given. A grade of C or better is required in order to use this course as a pre-requisite for 36-226 and 36-410.
Prerequisites: (21-111 and 21-112) or 21-120 or 21-256 or 21-259

36-220 Engineering Statistics and Quality Control

Fall and Spring: 9 units
This is a course in introductory statistics for engineers with emphasis on modern product improvement techniques. Besides exploratory data analysis, basic probability, distribution theory and statistical inference, special topics include experimental design, regression, control charts and acceptance sampling.
Prerequisites: 21-120 or 21-112

36-225 Introduction to Probability Theory

Fall and Summer: 9 units
This course is the first half of a year-long course which provides an introduction to probability and mathematical statistics for students in the data sciences. Topics include elementary probability theory, conditional probability and independence, random variables, distribution functions, joint and conditional distributions, law of large numbers, and the central limit theorem.
Prerequisites: (21-112 and 21-111) or 21-120 or 21-256 or 21-259

Course Website: http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/depar (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/depar/)

36-226 Introduction to Statistical Inference

Spring and Summer: 9 units
This course is the second half of a year-long course in probability and mathematical statistics. Topics include maximum likelihood estimation, confidence intervals, hypothesis testing, and properties of estimators, such as unbiasedness and consistency. If time permits there will also be a discussion of linear regression and the analysis of variance. A grade of C or better is required in order to advance to 36-401, 36-402 or any 36-46x course. Not open to students who have received credit for 36-626.
Prerequisites: 21-325 Min. grade C or 36-219 Min. grade C or 36-225 Min. grade C or 15-259 Min. grade C or 36-218 Min. grade C or 36-217 Min. grade C

36-235 Probability and Statistical Inference I

Fall: 9 units
This class is the first half of a two-semester, calculus-based course sequence that introduces theoretical aspects of probability and statistical inference to students. The material in this course and in 36-236 (Probability and Statistical Inference II) is organized so as to provide repeated exposure to essential concepts: the courses cover specific probability distributions and their inferential applications one after another, starting with the normal distribution and continuing with the binomial and Poisson distributions, etc. Topics specifically covered in 36-235 include basic probability, random variables, univariate and multivariate distribution functions, point and interval estimation, hypothesis testing, and regression, with the discussion being supplemented with computer-based examples and exercises (e.g., visualization and simulation). Given its organization, the course is only appropriate for those taking the full two-semester sequence, and thus it is currently open only to statistics majors (primary, additional, dual) and minors. (Check with the statistics advisors for the exact declaration deadline.) Non-majors/minors requiring a probability course are directed to take 36-225 or one of its analogues. A grade of C or better in 36-235 is required in order to advance to 36-236 (or 36-226) and/or 36-410. This course is not open to students who have received credit for 36-217, 36-218, 36-219, or 36-700, or for 21-325 or 15-259.
Prerequisites: (21-112 and 21-111) or 21-256 or 21-259 or 21-120

36-236 Probability and Statistical Inference II

Spring: 9 units
This class is the second half of a two-semester, calculus-based course sequence that introduces theoretical aspects of probability and statistical inference to students. The material in this course and in 36-235 (Probability and Statistical Inference I) is organized so as to provide repeated exposure to essential concepts: the courses cover specific probability distributions and their inferential applications one after another, starting with the normal distribution and continuing with the binomial and Poisson distributions, etc. Topics specifically covered in 36-236 include the binomial and related distributions, the Poisson and related distributions, and the uniform distribution, and how they are used in point and interval estimation, hypothesis testing, and regression. Also covered in 36-236 are topics related to multivariate distributions: marginal and conditional distributions, covariance, and conditional distribution moments. All discussion is supplemented with computer-based examples and exercises (e.g., visualization and simulation). Given its organization, the course is only appropriate for those who first take 36-235, and thus it is currently open only to statistics majors (primary, additional, dual) and minors, as well as to CS majors using both 36-235 and 36-236 to complete their probability requirement. All others are directed to take 36-226. A grade of C or better in 36-236 is required in order to advance to 36-401.
Prerequisite: 36-235 Min. grade C

36-290 Introduction to Statistical Research Methodology

Fall: 9 units
This is a first course in statistical practice, targeted to first-semester sophomores. It is designed as a high-level introduction to the ways by which statisticians go about approaching and analyzing quantitative observational data, thus preparing students for future work in capstone classes. Students in the course are taught the basic concepts of statistical learning and #8212;inference vs.prediction, supervised vs. unsupervised learning, regression vs. classification, etc. and #8212;and will reinforce this knowledge by applying, e.g., linear regression, random forest, principal components analysis, and/or hierarchical clustering and more to datasets provided by the instructor. Students will also practice disseminating the results of their analyses via oral presentations and posters. Analyses will be carried out using the R programming language.
Prerequisites: 36-220 or 70-207 or 36-207 or 36-200 or 36-247

Course Website: http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/depar (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/depar/)

36-297 Early Undergraduate Research

Fall and Spring: 6 units
This course is designed to give early undergraduate students (those who have not yet taken 36-401) experience navigating real data science research problems. Small groups of students are matched with clients and do supervised research for a semester. From an academic perspective, the course presents an opportunity for students to gain skills in, e.g., data acquisition and cleaning, exploratory data analysis, and basic statistical modeling; which skills are practiced is project-dependent. Additionally, the course will help students develop the professional skills necessary for successfully navigating team-based project delivery roles. Programming will be performed in R and/or Python; previous programming experience is not required.

36-300 Statistics & Data Science Internship

Summer: 3 units
The Department of Statistics and amp; Data Science considers experiential learning as an integral part of our program. One such option is through an internship. If a student has an internship, they dont have to register for this class unless they want it listed on their official transcripts. This process should be used by international students interested in Curricular Practical Training (CPT) and should also be authorized by the Office of International Education (OIE). More information regarding CPT is available on OIE's website. This course will be taken as Pass/Fail, and students will be charged tuition for 3 units. There is an approval process in order to register for this course. Please contact your advisor the Department of Statistics and amp; Data Science for more details.

36-301 Documenting Human Rights

Intermittent: 9 units
This course will teach students about the origins of modern human rights and the evolution of methods to document the extent to which these rights are being upheld or violated. The need to understand and document human rights issues is at the center of the most pressing current events. From threats to democracy and civil rights to work holding perpetrators of mass harm accountable in legal proceedings to efforts to quantify and advance economic, social, cultural, and environmental rights, making human rights violations visible is fundamental to achieving a more just world. We will begin with an overview of the history of human rights, the main philosophical and political debates in the field, and the most relevant organizations, institutions, and agreements. We will then delve into specific cases that highlight methodological opportunities and challenges, including: the identification of mass atrocity victims, the disappeared, and missing migrants; efforts to estimate civilian casualties in war; the documentation of police brutality and other human rights violations with smartphones; as well as the use of satellite imagery and drone footage for the documentation of genocide, environmental rights, and war crimes. We will critically assess the technical challenges that arise in each context and how the human rights and scientific communities have responded. After reviewing these cases, we will conclude by reflection on why the documentation of human rights actually matters and what happens to evidence once it is gathered. Students will then take what they've learned and do two multidisciplinary group projects, one involving the document of a rights violation in Western Pennsylvania and the other involving an international situation. Assignments include an essay, a data analysis assignment, and a group project that include a written component, quantitative and/or qualitative data analysis, and a presentation.

36-303 Sampling, Survey and Society

Spring: 9 units
This course will revolve around the role of sampling and sample surveys in the context of U.S. society and its institutions. We will examine the evolution of survey taking in the United States in the context of its economic, social and political uses. This will eventually lead to discussions about the accuracy and relevance of survey responses, especially in light of various kinds of nonsampling error. Students will be required to design, implement and analyze a survey sample.
Prerequisites: 70-208 or 36-236 or 36-218 Min. grade B or 36-208 or 36-202 or 36-309 or 36-220 or 36-226 or 36-326

36-309 Experimental Design for Behavioral & Social Sciences

Fall and Summer: 9 units
This course focuses on the statistical aspects of the design and analysis stages of planned experiments. The design stage focuses on determining how experimental factors are allocated, the sample size necessary to achieve adequate statistical power, and how subjects/variables are measured. The analysis stage focuses on how data are collected and which statistical models are most appropriate to answer the research questions of interest. Although students will have to do some computer programming to implement these statistical techniques, the most important aspect of the course will be on interpreting analyses' results (e.g., whether a given analysis is appropriate, to what extent that analysis can answer research questions of interest, and the broader implications of an analysis within the context of the experiment). In addition to a weekly lecture, students will attend a computer lab once a week to get guidance and hands-on practice implementing statistical techniques we learn in class.
Prerequisites: 36-218 or 70-207 or 36-326 or 36-226 or 36-220 or 15-260 or 36-247 or 36-200 or 36-236

Course Website: http://www.stat.cmu.edu/academics/courselist (http://www.stat.cmu.edu/academics/courselist/)

36-311 Statistical Analysis of Networks

Intermittent: 9 units
Networks are omnipresent. In this course, students will get an introduction to network science, mainly focusing on social network analysis. The course will start with some empirical background, and an overview of concepts used when measuring and describing networks. We will also discuss network visualization. Most traditional models cannot be applied straightforwardly to social network data, because of their complex dependence structure. We will discuss random graph models and statistical network models, that have been developed for the study of network structure and growth. We will also cover models of how networks impact individual behavior.
Prerequisite: 36-226

36-313 Statistics of Inequality and Discrimination

Intermittent: 9 units
Many social questions about inequality, injustice and unfairness are, in part, questions about evidence, data, and statistics. This class lays out the statistical methods which let us answer questions like "Does this employer discriminate against members of that group?", "Is this standardized test biased against that group?", "Is this decision-making algorithm biased, and what does that even mean?" and "Did this policy which was supposed to reduce this inequality actually help?" We will also look at inequality within groups, and at different ideas about how to explain inequalities between groups. The class will interweave discussion of concrete social issues with the relevant statistical concepts.
Prerequisite: 36-202

36-315 Statistical Graphics and Visualization

All Semesters: 9 units
Graphical displays of quantitative information take on many forms, and they help us understand data and statistical methods by (hopefully) clearly communicating arguments, results, and ideas. This course introduces students to the most common forms of graphical displays and their uses and misuses. Ideally, graphs are designed according to three key elements: The data structure, the graph's audience, and the designer's intended message. Students will learn how to create well-designed graphs and understand them from a statistical perspective. Furthermore, the course will consider complex data structures that are becoming increasingly common in data visualizations (temporal, spatial, and text data); we will discuss common ways to process these data that make them easy to visualize. As time permits, we may also consider more advanced graphical methods (e.g., interactive graphics and computer-generated animations). In addition to two weekly lectures, there will be weekly computer labs and homework assignments where students use R to visualize and analyze real datasets. Along the way, students also make monthly Piazza posts discussing the strengths and weaknesses of a graph they found online, thereby critiquing real graphical designs found in the wild. The course culminates in a group final project, where students make public-facing data visualizations and analyses for a real dataset. All assignments will be in R; although this is not a programming class, using programming-based statistical software like R is essential to create modern-day graphics, and this class will give you practice using this kind of software. Throughout, communication skills (usually written or visual, but sometimes spoken) will play an important role. Indeed, if it's true that "a picture speaks a thousand words," then ideally the one thousand words you are communicating with your graphics are statistically correct, clear, and compelling.
Prerequisites: 36-309 or 36-225 or 36-218 or 70-208 or 36-202 or 36-219 or 36-235 or 36-208 or 15-259 or 21-325

36-318 Introduction to Causal Inference

Intermittent: 9 units
Many social science and scientific inquiries can be framed as causal questions. Does a new cancer treatment cause a reduction in mortality? Do financial grants cause students to do better in college? Does a new public policy cause an increase in voter turnout? When tackling these questions, we frequently come across the phrase "correlation does not imply causation." If that's the case, then what does imply causation? In this course, we will discuss causal inference methods for measuring causal effects of different interventions (e.g., drug treatments, financial grants, and public policies). First, we will discuss how experiments and #8212;-where interventions are randomized among subjects and #8212;-can imply causation when an appropriate experimental design and statistical analysis is used. Then, we will discuss how observational studies and #8212;-where interventions are not randomized and #8212;-can also imply causation when approaches like propensity score methods, matching, and doubly robust estimation are employed. Finally, we will discuss instrumental variables and regression discontinuity designs and #8212;-which are frequently used in medicine and public policy for establishing causal inferences. Throughout we will use R to conduct causal analyses. A working knowledge of regression is encouraged, but regression will also be discussed and taught during much of the course.
Prerequisites: 15-259 Min. grade C or 36-225 Min. grade C or 36-219 Min. grade C or 36-218 Min. grade C or 36-235 Min. grade C or 21-325 Min. grade C

36-326 Mathematical Statistics (Honors)

Spring: 9 units
This course is a rigorous introduction to the mathematical theory of statistics. A good working knowledge of calculus and probability theory is required. Topics include maximum likelihood estimation, confidence intervals, hypothesis testing, Bayesian methods, and regression. A grade of C or better is required in order to advance to 36-401, 36-402 or any 36-46x course. Not open to students who have received credit for 36-625.
Prerequisites: 15-359 or 21-325 or 36-217 or 36-225 with a grade of A AND advisor approval. Students interested in the course should add themselves to the waitlist pending review.
Prerequisites: 36-218 Min. grade A or 21-325 Min. grade A or 36-217 Min. grade A or 36-225 Min. grade A or 15-359 Min. grade A

36-350 Statistical Computing

All Semesters: 9 units
Statistical Computing is a one-semester course that will introduce you to the fundamentals of computational data analysis, as carried out in the R programming language, and to the fundamentals of working with relational databases, such as SQLite. No previous knowledge of either is required.
Prerequisites: 21-325 Min. grade C or 36-218 Min. grade C or 36-219 Min. grade C or 36-225 Min. grade C or 36-217 Min. grade C or 15-259 Min. grade C or 36-235 Min. grade C

36-390 Study Abroad Experience in Statistics and Data Science

Summer: 9 units
Statistics and Data Science at the Monteverde Institute in Costa Rica. This is a five-week study abroad experience in which students will directly engage with, and will process, visualize, and/or analyze data collected by, researchers at the institute. Students will also have the opportunity to participate in data collection, as appropriate. The mission of the institute is to promote sustainable practices that benefit both the local community and local wildlife, and the data that students can examine include, but are not limited to, ecological data on bats, birds, reforestation, and stream beds, as well as data arising from community surveys. This course does not require prior knowledge of, or exposure to, data processing, visualization, or analysis techniques beyond what is covered in the prerequisite classes, and necessary techniques and methods will be introduced and discussed in daily classes. Project goals will be modified for students with more advanced backgrounds (e.g., students who have completed 36-401 and 36-402). The 2024 class is limited to six students overall.

36-400 Introduction to Statistical Modeling and Learning

Spring: 9 units
This course is a high-level introduction both to fundamental concepts of probability and statistics and to the ways by which statisticians go about approaching and analyzing data. The course will cover data processing, exploratory data analysis, parameter estimation and hypothesis testing, clustering, and common regression and classification models. Students will carry out work using the R and Python programming languages. This course is open only to students not majoring in Stat and amp; DS who have taken the prerequisite courses.
Prerequisites: 36-200 and (36-309 or 36-202 or 36-290)

36-401 Modern Regression

Fall: 9 units
This course is an introduction to the real world of statistics and data analysis using linear regression modeling. We will explore real data sets, examine various models for the data, assess the validity of their assumptions, and determine which conclusions we can make (if any). We will use the R programming language to implement our analyses and produce graphs and tables of results. Data analysis is a bit of an art; there may be several valid approaches. We will strongly emphasize the importance of critical thinking about the data and the question of interest. Our overall goal is to use data and a basic set of modeling tools to answer substantive questions, and to present the results in a scientific report.
Prerequisites: (36-236 Min. grade C or 36-326 Min. grade C or 36-226 Min. grade C or 36-218 Min. grade B) and (21-242 or 21-240 or 21-241)

36-402 Advanced Methods for Data Analysis

Spring: 9 units
This course introduces modern methods of data analysis, building on the theory and application of linear models from 36-401. Topics include nonlinear regression, nonparametric smoothing, density estimation, generalized linear and generalized additive models, simulation and predictive model-checking, cross-validation, bootstrap uncertainty estimation, multivariate methods including factor analysis and mixture models, and graphical models and causal inference. Students will analyze real-world data from a range of fields, coding small programs and writing reports.
Prerequisite: 36-401 Min. grade C

36-410 Introduction to Probability Modeling

Spring: 9 units
An introductory-level course in stochastic processes. Topics typically include Poisson processes, Markov chains, birth and death processes, random walks, recurrent events, and renewal theory. Examples are drawn from reliability theory, queuing theory, inventory theory, and various applications in the social and physical sciences.
Prerequisites: 21-325 or 15-259 or 36-225 or 36-235 or 36-217

36-460 Special Topics: Sports Analytics

Spring: 9 units
This course introduces students to fundamental topics in sports analytics and the relevant statistical methods for tackling problems in this growing area. The first half of the course will cover foundational topics in sports analytics including models for the expected value of game states, win probability, team ratings, and hierarchical models for player evaluation. The second half of the course will focus on spatio-temporal methods appropriate for modeling complex player-tracking data. The focus is on understanding the foundations of the considered methods and introducing software for implementation. Students will develop their own sports analytics project using techniques covered in the course for their final assessment.
Prerequisite: 36-401 Min. grade C

36-461 Special Topics: Statistical Methods in Epidemiology

Intermittent: 9 units
Epidemiology is concerned with understanding factors that cause, prevent, and reduce diseases by studying associations between disease outcomes and their suspected determinants in human populations. Epidemiologic research requires an understanding of statistical methods and design. Epidemiologic data is typically discrete, i.e., data that arise whenever counts are made instead of measurements. In this course, methods for the analysis of categorical data are discussed with the purpose of learning how to apply them to data. The central statistical themes are building models, assessing fit and interpreting results. There is a special emphasis on generating and evaluating evidence from observational studies. Case studies and examples will be primarily from the public health sciences.
Prerequisite: 36-401 Min. grade C

Course Website: http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/depar (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/depar/)

36-462 Special Topics: Statistical Machine Learning

Intermittent: 9 units
Data mining is the science of discovering patterns and learning structure in large data sets. Covered topics include information retrieval, clustering, dimension reduction, regression, classification, and decision trees.
Prerequisite: 36-401 Min. grade C

Course Website: http://www.stat.cmu.edu/academics/courselist (http://www.stat.cmu.edu/academics/courselist/)

36-463 Special Topics: Multilevel and Hierarchical Models

Intermittent: 9 units
Multilevel and hierarchical models are among the most broadly applied "sophisticated" statistical models, especially in the social and biological sciences. They apply to situations in which the data "cluster" naturally into groups of units that are more related to each other than they are the rest of the data. In the first part of the course we will review linear and generalized linear models. In the second part we will see how to generalize these to multilevel and hierarchical models and relate them to other areas of statistics, and in the third part of the course we will learn how Bayesian statistical methods can help us to build, estimate and diagnose problems with these models using a variety of data sets and examples.
Prerequisite: 36-401 Min. grade C

Course Website: http://www.stat.cmu.edu/academics/courselist (http://www.stat.cmu.edu/academics/courselist/)

36-464 Special Topics: Psychometrics: A Statistical Modeling Approach

Intermittent: 9 units
Much of the social, educational, policy, and professional worlds involve measuring the skills, abilities, attitudes, decision-making, etc. of people and #8212; from SAT's and GRE's for school, to 360-evaluations in business. This is the field of modern psychometrics, and it involves (at least) two kinds of craft: designing good sets of questions, and designing and fitting statistical models that extract the information we want from the responses to those questions. In this course we will touch on both kinds of craft, but we will concentrate on the second: what do statistical models for psychometric data look like, and how can we design, fit, and use them in practice? We will look at these models from a variety of statistical perspectives, but we will concentrate on the applied Bayesian point of view.
Prerequisite: 36-401 Min. grade C

Course Website: http://www.stat.cmu.edu/academics/courselist (http://www.stat.cmu.edu/academics/courselist/)

36-465 Special Topics: Conceptual Foundations of Statistical Learning

Intermittent: 9 units
This class is an introduction to the foundations of statistical learning theory, and its uses in designing and analyzing machine-learning systems. Statistical learning theory studies how to fit predictive models to training data, usually by solving an optimization problem, in such a way that the model will predict well, on average, on new data. The course will focus on the key concepts and theoretical tools, at a level accessible to students who have taken 36-401 and its pre-requisites. The course will also illustrate those concepts and tools by applying them to carefully selected kinds of machine learning systems (such as kernel machines). Students wanting exposure to a broad range of algorithms and applications would be better served by 36-462/662 ("Data Mining"). This class is for those who want a deeper understanding of the principles underlying all machine learning methods.
Prerequisite: 36-401 Min. grade C

36-466 Special Topics: Statistical Methods in Finance

Intermittent: 9 units
Financial econometrics is the interdisciplinary area where we use statistical methods and economic theory to address a wide variety of quantitative problems in finance. These include building financial models, testing financial economics theory, simulating financial systems, volatility estimation, risk management, capital asset pricing, derivative pricing, portfolio allocation, proprietary trading, portfolio and derivative hedging, and so on and so forth. Financial econometrics is an active field of integration of finance, economics, probability, statistics, and applied mathematics. Financial activities generate many new problems and products, economics provides useful theoretical foundation and guidance, and quantitative methods such as statistics, probability and applied mathematics are essential tools to solve quantitative problems in finance. Professionals in finance now routinely use sophisticated statistical techniques and modern computation power in portfolio management, proprietary trading, derivative pricing, financial consulting, securities regulation, and risk management.
Prerequisite: 36-401

36-467 Special Topics: Data over Space & Time

Intermittent: 9 units
This course is an introduction to the opportunities and challenges of analyzing data from processes unfolding over space and time. It will cover basic descriptive statistics for spatial and temporal patterns; linear methods for interpolating, extrapolating, and smoothing spatio-temporal data; basic nonlinear modeling; and statistical inference with dependent observations. Class work will combine practical exercises in R, a little mathematics on the underlying theory, and case studies analyzing real problems from various fields (economics, history, meteorology, ecology, etc.). Depending on available time and class interest, additional topics may include: statistics of Markov and hidden-Markov (state-space) models; statistics of point processes; simulation and simulation-based inference; agent-based modeling; dynamical systems theory.
Prerequisite: 36-401 Min. grade C

Course Website: http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/depar (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/depar/)

36-468 Special Topics: Text Analysis

Intermittent: 9 units
The analysis of language is concerned with how variables relate to people (their gender, age, and location, for example), how variables relate to use (such as writing in different academic disciplines), and how variables change over time. While we are surrounded by data that might potentially shed light on many of these questions, working with real-world linguistic data can present some unique challenges in sampling, in the distribution of features, and in their high dimensionality. In this course, we work through some of these issues, paying particular attention to the aligning of the statistical questions we want to investigate with the choice of statistical models, as well as focusing on the interpretation of results. Analysis will be carried out in R and students will develop a suite of tools as they work through their course projects.
Prerequisites: 36-218 Min. grade B or 36-226 Min. grade C or 36-236 Min. grade C

36-469 Special Topics: Statistical Genomics and High Dimensional Inference

Intermittent: 9 units
The field of computational and statistical genomics focuses on developing and applying computationally efficient and statistically robust methods to sort through increasingly rich and massive genome wide data sets to identify complex genetic patterns, gene interactions, and disease associations. Because the genome is vast, analytical approaches require high dimensional statistical approaches such as multiple testing, dimension reduction techniques, regularization and high dimensional regression analysis, best linear unbiased prediction models, networks and graphical models. In this course, we will motivate these topics using data obtained from the human genetic and genomic literature. No prior knowledge in biology is required.
Prerequisite: 36-401 Min. grade C

36-470 Special Topics: Statistical Methods in Health Sciences

Intermittent: 9 units
As the volume of health and clinical data continues to expand, the integration of statistical and machine learning methods becomes increasingly important for enhancing healthcare efficiency. However, there are challenges in modeling health data, for example, annotated data is often limited or subject to incompleteness. In this course, we will introduce statistical methods that address these challenges, including survival analysis, latent variable models, clustering, semi-supervised learning, and so on. An emphasis will put on understanding methodological foundations and how to appropriately apply methods to health data. Through homework assignments, labs, paper presentations, and a final project, students will gain hands-on-experience in applying statistical methods to solve problems arising from health sciences.
Prerequisite: 36-401 Min. grade C

36-471 Special Topics: Time Series

Fall: 9 units
This course covers time series analysis from fundamentals to advanced models in both time and frequency domains. The focus is on practical execution and interpretation of time series analyses with realistic real-world data.
Prerequisite: 36-401

36-490 Undergraduate Research

Fall and Spring: 9 units
This course is designed to give undergraduate students experience using statistics in real research problems. Small groups of students are matched with clients and do supervised research for a semester. From an academic perspective, the course presents an opportunity for students to gain skills in approaching a research problem, critical thinking, and statistical analyses. Additionally, the course will help students develop the professional skills necessary for successfully navigating team-based project delivery roles. Client-facing and collaborative skills will be emphasized within a team setting, and students will learn leading practices for engaging stakeholders as well as gain a conceptual understanding of leading practices for project delivery.

36-497 Corporate Capstone Project

Fall and Spring: 9 units
This course is designed to give undergraduate students experience applying statistics data science methodology to real industry projects. Small groups of students will be matched with industry clients and do supervised projects for a semester. From an academic perspective, the course presents an opportunity for students to gain skills in approaching a research problem, critical thinking, and statistical analyses. Additionally, the course will help students develop the professional skills necessary for successfully navigating team-based project delivery roles. Client-facing and collaborative skills will be emphasized within a team setting, and students will learn leading practices for engaging stakeholders as well as gain a conceptual understanding of leading practices for project delivery. The industry clients will change and rotate each semester; available projects will be advertised prior to the first week of class. The course size is limited; students apply the previous semester and placed on the course waitlist until project matching is performed. Students with skill sets matching project needs will be given priority. We will also take into consideration whether or not a student has had a recent prior corporate capstone experience with the goal of providing experiences to a broad group of qualified students. Note that there is no guarantee a waitlisted student will be matched to a project in any given semester.

36-498 Corporate Capstone II

Fall and Spring
This course allows students to continue work on projects begun as part of 36-497, Corporate Capstone Project. Enrollment is at the discretion of the external advisor for the 36-497 project and the Department of Statistics and amp; Data Science.

36-680 Quantitative Financial Analytics and Algorithmic Trading

Fall and Spring: 12 units
Algorithmic trading serves as a practical application of software engineering and data science methodologies and quantitative analysis techniques within the context of financial markets. This project-based course offers an introduction to algorithmic trading and the principles behind it, while emphasizing universally applicable engineering concepts and data-driven methodologies. Students will gain an understanding of the fundamentals of financial markets and trading systems, learn how to manage data, generate signals, backtest strategies, and use APIs to execute trades. Additionally, they will apply risk management principles, position sizing, and software development best practices such as unit testing in Python. Most importantly, the course will teach students specific thinking patterns and data science methodologies that can be applied across various engineering and data analysis fields. Students will be equipped with a toolbox needed to continue researching trading strategies, predictive analytics, or other data science-related topics independently. Following condensed lecture videos, the course will emulate a professional environment through a series of individual assignments culminating in a functional project. Delivery of the project will be guided by direct instruction, Q and amp;A calls, and an online chat group with the lecturers, similar to a real workplace. Students will deliver a functional project in Python, according to a specification, while also taking exams on the theoretical materials covered in the lectures. Student progress is assessed through the delivery of practical projects according to a specification and evaluation criteria. While there are no prerequisites for this course, an understanding of statistics, probabilities, hypothesis testing, measures of spread, confidence intervals, and related topics is assumed.

36-700 Probability and Mathematical Statistics

Fall: 12 units
This is a one-semester course covering the basics of statistics. We will first provide a quick introduction to probability theory, and then cover fundamental topics in mathematical statistics such as point estimation, hypothesis testing, asymptotic theory, and Bayesian inference. If time permits, we will also cover more advanced and useful topics including nonparametric inference, regression and classification. Prerequisites: one- and two-variable calculus and matrix algebra. Graduate students in degree-seeking programs are given priority.

Dietrich College Interdisciplinary Majors

When addressing complex issues, we often rely on approaches that take advantage of a variety of relevant disciplines. The college houses the special category of “interdepartmental majors” for programs where this interdisciplinary approach is most pronounced and in which the varied disciplinary perspectives are most fully integrated. These majors are presented here separately, rather than as departmentally-based options, to reflect and underscore their sponsorship by more than one academic department and the unique features that follow from this structure.

Interdepartmental majors are administered by the academic department of the major's faculty advisor.

The Major in Economics and Politics

Audrey Kurth Cronin, *Director, Trustees Professor of Security and Technology*
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Politics and economics are deeply interconnected. Political institutions and decision-making impact economic growth, income distribution, and many other aspects of economic life. Both fiscal and monetary policies affect the economy: but these policies also reflect political considerations and influence political outcomes. For example, while the United Nations is often thought of in purely political terms, the Security Council can and does impose sanctions on countries-- an example of an economic policy used for political change.

The Economics and Politics major is offered jointly between the Carnegie Mellon Institute for Strategy and Technology (https://www.cmu.edu/cmist/) (CMIST) and the Undergraduate Economics Program (https://www.cmu.edu/tepper/programs/undergraduate-economics/) (UEP). The major will appeal to any student interested in the design, evaluation, and political implementation of economic policy. It will be especially attractive to students considering careers in politics, government agencies, political and business consulting, lobbying, or the law.

The BS in Economics and Politics is an interdisciplinary major. The major will develop the political context and underpinnings of economic policy making. It will explore how political institutions resolve the tradeoffs and disagreements associated with policymaking and how they can facilitate or impede desirable economic outcomes.

CMIST's strengths lie in topics such as emerging technology, national security, and grand strategy. Economic policy is one facet of grand strategy through which governments pursue domestic and international goals. This major will enable students to understand economic statecraft from a broad perspective. It will address key issues such as how multilateral economic institutions such as the IMF and World Bank use economic coercion. Whether coercion is successful or not depends not only on the levers of power but on also on variations in regime structures, alongside complex linkages in the international economy. For example, the viability of the “Euro Zone” depends on whether the political-economic agreements necessary to mitigate institutional weaknesses are politically feasible or destined to failure. In short, international economics affects everything from human rights practices to trade patterns to energy markets to tech company investments to global compliance with climate change treaties.

Economics and Politics is available as both a primary and an additional major. The requirements are the same for both.

Curriculum

A maximum of four courses may double count between the Economics and Politics major and any other majors or minor. Unlimited double counting is permitted with general education requirements.

Students must earn a grade of "C" or better in all courses taken in the Department of Economics (73-xxx).

Mathematics (19 units)

Students must complete all of the following courses.

21-120	Differential and Integral Calculus	10
or 21-112	Calculus II	
21-256	Multivariate Analysis	9
or 21-259	Calculus in Three Dimensions	

Economics Core (54 units)

Students must complete all of the following courses.

73-102	Principles of Microeconomics *	9
or 73-104	Principles of Microeconomics Accelerated	
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9
73-265	Economics and Data Science	9
73-274	Econometrics I	9

***Students who place out of 73-102 based on the economics placement exam will receive a pre-req waiver for 73-102 and are waived from taking 73-102**

CMIST Core (48 units)

Students must complete all of the following courses.

84-104	Decision Processes in American Political Institutions	9
84-226	International Relations	9
84-266	Research Design for Political Science	9
84-275	Comparative Politics	9
84-310	Policy in a Global Economy 1: International Trade and Trade Policy	6
84-311	Policy in a Global Economy 2: International Macroeconomics and Finance	6

Communication (9 units)

Students must complete the following course:

84-250	Writing for Political Science and Policy	9

Electives (27 units)

Majors are required to take 27 units (usually three courses) from the elective lists below. At least 9 units (typically one course) must be taken from Economics (73-xxx) and at least 9 units (typically one course)) must be taken from the Carnegie Mellon Institute for Strategy and Technology (84-xxx). Students may complete electives through coursework in the Carnegie Mellon University Washington Semester Program (CMU/WSP) (https://www.cmu.edu/cmist/washington-center/washington-semester-program/).

Economics Electives

73-328	Health Economics	12
73-332	Political Economy	9
73-338	Financial Crises and Risk	9
73-348	Behavioral Economics	9
73-352	Public Economics	9
73-353	Financial Regulation in the Digital Age	9
73-365	Firms, Market Structures, and Strategy	9
73-421	Emerging Markets	9
73-427	Sustainability, Energy, and Environmental Economics	9

CMIST: Political Science and International Relations Electives

84-120	Introduction to US Constitutional Law	9
84-200	Security War Game Simulation	6
84-252	Briefing in the Policy World	6
84-274	An Introduction to Technology and War	9
84-280	Popcorn and Politics: American Foreign Policy at the Movies	10
84-303	International Human Rights	6
84-304	In the News: Analysis of Current US National Security Priorities	6
84-306	Latin American Politics	9
84-309	American Political Divides and Great Debates	9

84-312	Terrorism in Sub-Saharan Africa	6
84-313	International Organizations and Law	6
84-317	Defense PPBE in the Age of Emerging Technologies	6
84-318	Politics of Developing Nations	9
84-319	Civil-Military Relations	9
84-322	Nonviolent Conflict and Revolution	9
84-323	War and Peace in the Contemporary Middle East	9
84-324	The Future of Democracy	9
84-325	Contemporary American Foreign Policy	9
84-328	Military Strategy and Doctrine	9
84-329	Asian Strategies	6
84-332	Contemporary US Constitutional Law Issues Taught in Washington, DC, through CMU/WSP	6
84-338	Analysis of US Presidential Powers Taught in Washington, DC, through CMU/WSP	6
84-349	Digital Diplomacy: Cybersecurity Challenges and Global Governance	9
84-350	A Strategist's Introduction to Artificial Intelligence	9
84-351	Bias, Objectivity, and the Media's Role in Politics	6
84-352	Representation and Voting Rights	9
84-354	The American Experiment: Unravelling the US Electoral System	6
84-355	Democracy's Data: Analytics and Insights into American Elections	9
84-360	CMU/WSP: Internship Seminar Taught in Washington, DC, through CMU/WSP	24
84-362	Diplomacy and Statecraft	9
84-363	Click. Hack. Rule: Understanding the Power & Peril of Cyber Conflict	9
84-365	The Politics of Fake News and Misinformation	9
84-367	The Politics of Antisemitism	9
84-369	Decision Science for International Relations	9
84-370	Nuclear Security & Arms Control	9
84-372	Space and National Security	9
84-373	Emerging Technologies and International Law	9
84-380	US Grand Strategy	9
84-383	Cyber Policy as National Policy	6
84-386	The Privatization of Force	9
84-387	Remote Systems and the Cyber Domain in Conflict	9
84-388	Concepts of War and Cyber War	6
84-389	Terrorism and Insurgency	9
84-390	Social Media, Technology, and Conflict	9
84-393	Legislative Decision Making: US Congress	9
84-402	Judicial Politics and Behavior	9
84-405	The Future of Warfare	9
84-440	Collaborative Research in Political Science	Var.
Additional Electives		
19-411	Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech	9
19-425	Sustainable Energy for the Developing World	9
70-365	International Trade and International Law	9
70-430	International Management	9
79-280	Coffee and Capitalism	9
79-318	Sustainable Social Change: History and Practice	9
80-135	Introduction to Political Philosophy	9
80-136	Social Structure, Public Policy & Ethics	9
80-335	Social and Political Philosophy	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9
88-366	Behavioral Economics of Poverty and Development	9
88-411	Rise of the Asian Economies	9

CAPSTONE (18-30 units)

Students must complete all of the following courses.

84-450	Policy Seminar	6-12
or 84-336	Implementing Public Policy: From Good Idea To Reality	
or 84-339	Seminar in Public Policy Research	
73-497	Senior Project or Senior Honors Thesis in Dietrich or Tepper (18 units total)	12

Note: Students in the BS in Economics and Politics who complete a Dietrich or Tepper Honors Thesis in economics may use 73-497 (Senior Project) as an economics elective.

DOUBLE-COUNTING RESTRICTION

A maximum of four courses may double count with another major or minor.

Sample four-year plan

These sample curricula represent a plan for completing the requirements for the B.S. in Economics and Politics. Economics and Politics students are encouraged to spend a semester studying and interning in Washington, DC, through the CMU/WSP (https://www.cmu.edu/cmist/washington-center/washington-semester-program/), and/or study abroad. The plan below demonstrates that a semester off-campus fits well into the curriculum. Students may declare the BS in Economics and Politics as early as the second semester of the freshman year and should consult frequently with the Economics and Politics advisors about their course of study. Please note that this is only a sample plan of study and not the only possible plan of study. The Economics and Politics major and Dietrich College General Education curricula provide a high degree of flexibility in sequencing and coursework. Double counting between the major and General Education requirements is unlimited. The plan below shows a very conservative view of double counting.

First-Year		**Second-Year**	
Fall	**Spring**	**Fall**	**Spring**
21-120 Differential and Integral Calculus	21-256 Multivariate Analysis	73-230 Intermediate Microeconomics	73-240 Intermediate Macroeconomics
36-200 Reasoning with Data	73-103 Principles of Macroeconomics	73-265 Economics and Data Science	73-274 Econometrics I
73-102 Principles of Microeconomics	84-275 Comparative Politics	84-226 International Relations	84-250 Writing for Political Science and Policy
84-104 Decision Processes in American Political Institutions	First-Year Writing	84-266 Research Design for Political Science	84-310 Policy in a Global Economy 1: International Trade and Trade Policy
Grand Challenge Seminar	Disciplinary Perspectives: Humanities	General Education	84-311 Policy in a Global Economy 2: International Macroeconomics and Finance
99-101 Core@CMU			General Education

Third-Year		**Fourth-Year**	
Fall	**Spring**	**Fall**	**Spring**
General Education	CMU/WSP or Study Abroad	73-497 Senior Project	84-450 Policy Seminar (if student does not participate in CMU/WSP)
General Education	Explore	General Education	General Education
General Education	Explore	Economics & Politics Elective	Explore
General Education	Explore	Economics & Politics Elective	Explore
Economics & Politics Elective	Explore	Explore	Explore

The Major in Economics and Statistics

Amanda Mitchell, *Statistics & Data Science Academic Program Manager*
Stephen Pajewski, *Economics Senior Academic Advisor and Program Manager*

Statistics & Data Science Location: Baker Hall 129
statadvising@andrew.cmu.edu (statadvising@stat.cmu.edu)

Economics Location: Tepper 2400
econprog@andrew.cmu.edu

The B.S. in Economics and Statistics is jointly advised by the Department of Statistics and Data Science and the Undergraduate Economics Program.

The Major in Economics and Statistics provides an interdisciplinary course of study aimed at students with a strong interest in the empirical analysis of economic data. With joint curriculum from the Department of Statistics and Data Science and the Undergraduate Economics Program, the major provides students with a solid foundation in the theories and methods of both fields. Students in this major are trained to advance the understanding of economic issues through the analysis, synthesis and reporting of data using the advanced empirical research methods of statistics and econometrics. Graduates are well positioned for admission to competitive graduate programs, including those in statistics, economics and management, as well as for employment in positions requiring strong analytic and conceptual skills - especially those in economics, finance, education, and public policy.

All economics courses counting towards an economics degree must be completed with a grade of "C" or higher.

Curriculum

The requirements for the B.S. in Economics and Statistics are the following:

1. MATHEMATICAL FOUNDATIONS (PREREQUISITES) 29-42 UNITS

Mathematics is the language in which statistical models are described and analyzed, so some experience with basic calculus and linear algebra is an important component for anyone pursuing a program of study in Economics and Statistics.

Calculus

Complete one of the two following sequences of mathematics courses at Carnegie Mellon, each of which provides sufficient preparation in calculus:

Sequence 1

21-111	Calculus I	10
21-112	Calculus II	10

and *one* of the following:

21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	10
21-268	Multidimensional Calculus	11

Sequence 2

21-120	Differential and Integral Calculus	10

and *one* of the following:

21-256	Multivariate Analysis	9
21-259	Calculus in Three Dimensions	10
21-268	Multidimensional Calculus	11

NOTES:

- Passing the MSC 21-120 assessment test is an acceptable alternative to completing 21-120.

Note: Taking/having credit for both 21-111 and 21-112 is equivalent to 21-120. The Mathematical Foundations total is then 48-49 units. The Economics and Statistics major would then total 201-211 units.

Linear Algebra

One of the following three courses:

21-240	Matrix Algebra with Applications	10
21-241	Matrices and Linear Transformations	11
21-242	Matrix Theory	11

Note: 21-241 and 21-242 are intended only for students with a very strong mathematical background.

II. Foundations 54 units

2. Economics Foundations 18 UNITS

Take one of the following courses:		
73-102	Principles of Microeconomics *	9
73-104	Principles of Microeconomics Accelerated **	9
Take the following course:		
73-103	Principles of Macroeconomics	9

*Students who place out of 73-102 based on the economics placement exam will receive a pre-req waiver for 73-102 and are waived from taking 73-102

**This course requires students to complete a 4 or 5 on the AP Microeconomics exam or qualifying score on the IB/Cambridge Exams. 73-104 will substitute for any 73-102 prerequisite requirement in other courses. 73-104 is a more rigorous introduction to microeconomics, is taught at a faster pace than 73-102, and dives a bit deeper into key topics. It is designed for students who have prior knowledge to fundamental economic concepts through AP/IB/Cambridge coursework. Enrollment in 73-104 requires special permission. Students who wish to take this course should add themselves to the 73-104 waitlist once registration opens. The Tepper School will verify the advancement placement scores and will enroll students in 73-104

3. Statistical Foundations 36 UNITS

DATA ANALYSIS

Data analysis is the art and science of extracting insight from data. The art lies in knowing which displays or techniques will reveal the most interesting features of a complicated data set. The science lies in understanding the various techniques and the assumptions on which they rely. Both aspects require practice to master.

The Beginning Data Analysis courses give a hands-on introduction to the art and science of data analysis. The courses cover similar topics but differ slightly in the examples they emphasize. 36-200 draws examples from many fields and satisfy the DC College Core Requirement in Statistical Reasoning. This course is therefore recommended for students in the college. (Note: a score of 5 on the Advanced Placement [AP] Exam in Statistics may be used to waive this requirement). 36-220 emphasizes examples in engineering.

The Intermediate Data Analysis courses build on the principles and methods covered in the introductory course, and more fully explore specific types of data analysis methods in more depth.

The Advanced Data Analysis courses draw on students' previous experience with data analysis and understanding of statistical theory to develop advanced, more sophisticated methods. These core courses involve extensive analysis of real data with emphasis on developing the oral and writing skills needed for communicating results.

Sequence 1 (For students beginning their freshman or sophomore year)

Beginning*

Choose *one* of the following courses:

36-200	Reasoning with Data *	9
36-220	Engineering Statistics and Quality Control	9

*A score of 5 on the Advanced Placement (AP) Exam in Statistics may be used to waive this requirement. 36-220 emphasizes examples in engineering and Architecture.

Note: Students who enter the program with 36-235 or 36-236 should discuss options with an advisor. Any 36-300 or 36-400 level course in Data Analysis that does not satisfy any other requirement for the Economics and Statistics Major may be counted as a Statistical Elective.

Intermediate*

Choose *one* of the following courses:

36-202	Methods for Statistics & Data Science **	9
36-290	Introduction to Statistical Research Methodology	9
36-309	Experimental Design for Behavioral & Social Sciences	9

* Or extra data analysis course in Statistics
** Must take prior to 36-401 Modern Regression, if not, an additional Advanced Statistics Elective is required.

Advanced Statistics Elective
Choose *two* of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-313	Statistics of Inequality and Discrimination	9
36-315	Statistical Graphics and Visualization	9
36-318	Introduction to Causal Inference	9
36-460	Special Topics: Sports Analytics	9
36-461	Special Topics: Statistical Methods in Epidemiology	9

36-462	Special Topics: Statistical Machine Learning	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Psychometrics: A Statistical Modeling Approach	9
36-465	Special Topics: Conceptual Foundations of Statistical Learning	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-469	Special Topics: Statistical Genomics and High Dimensional Inference	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

Sequence 2 (For students beginning later in their college career)

Advanced Statistics Electives
Choose *three* of the following courses:

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-313	Statistics of Inequality and Discrimination	9
36-315	Statistical Graphics and Visualization	9
36-318	Introduction to Causal Inference	9
36-460	Special Topics: Sports Analytics	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Statistical Machine Learning	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Psychometrics: A Statistical Modeling Approach	9
36-465	Special Topics: Conceptual Foundations of Statistical Learning	9
36-466	Special Topics: Statistical Methods in Finance	9
36-467	Special Topics: Data over Space & Time	9
36-468	Special Topics: Text Analysis	9
36-469	Special Topics: Statistical Genomics and High Dimensional Inference	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

**All Special Topics are not offered every semester, and new Special Topics are regularly added. See section 5 for details.

III. Disciplinary Core — 136-139 units

1. Economics Core — 45 UNITS

73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9
73-265	Economics and Data Science	9
73-274	Econometrics I	9
73-374	Econometrics II	9

2. Statistics Core — 36 UNITS

Take one of the following courses:		
36-235	Probability and Statistical Inference I *#	9
36-225	Introduction to Probability Theory	9
Take one of the following courses:		
36-236	Probability and Statistical Inference II **	9
36-226	Introduction to Statistical Inference	9
36-326	Mathematical Statistics (Honors)	9
Take both of the following courses:		
36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9

*In order meet the prerequisite requirements for the major, a grade of C or better is required in 36-235 (or equivalents), 36-236 or 36-326 and 36-401.

#It is possible to substitute 36-218, 36-219, 36-225or 21-325 for 36-235. 36-235 is the standard introduction to probability, 36-219 is tailored for engineers and computer scientists, 36-218 is a more mathematically rigorous class for Computer Science students and more mathematically advanced Statistics students (Statistics students need advisor approval to enroll), and 21-325 is a rigorous Probability Theory course offered by the Department of Mathematics.

**It is possible to substitute 36-226 or 36-326 for 36-236. 36-236 is the standard introduction to statistical inference.

Please note that students who complete 36-235 are expected to take 36-236 to fulfill their theory requirements. Students who choose to take 36-225 instead will be required to take 36-226 afterward, they will not be eligible to take 36-236.

3. Statistical Computing — 19-21 UNITS

Take one of the following two courses:		
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
Complete the following course:		
36-350	Statistical Computing	9

4. Advanced Electives — 36 units

Students must take two advanced Economics elective courses (numbered 73-300 through 73-495, excluding 73-374) and two (or three - depending on previous coursework, see Section 3) advanced Statistics elective courses (numbered 36-303, 36-311, 36-313, 36-315, 36-318, 36-46x, 36-490, or 36-497).

Total number of units for the major	**219-235 Units**
Total number of units for the degree	**360 Units**

Professional Development

While not required, students are strongly encouraged to take advantage of professional development opportunities and/or coursework. One option is , a fall-only course that provides information about careers in Economics, job search strategies, and research opportunities. The Department of Statistics and Data Science also offers a series of workshops pertaining to resume preparation, graduate school applications, careers in the field, among other topics. Students should also take advantage of the Career and Professional Development Center.

Additional Major in Economics and Statistics

Students who elect Economics and Statistics as an additional major must fulfill all Economics and Statistics degree requirements. Majors in many other programs would naturally complement an Economics and Statistics Major, including Tepper's undergraduate business program, Social and Decision Sciences, Policy and Management, and Psychology.

With respect to double-counting courses, it is departmental policy that students must have at least six courses [three Economics (73-xxx) and three Statistics (36-xxx)] that do *not* count for their primary major. If students do not have at least three ECON and three STA classes, they will need to take additional advanced data analysis or economics electives, depending on where the double-counting issue is.

Students are advised to begin planning their curriculum (with appropriate advisors) as soon as possible. This is particularly true if the other major has a complex set of requirements and prerequisites or when many of the other major's requirements overlap with the requirements for a Major in Economics and Statistics.

Substitutions and Waivers

Many departments require Statistics courses as part of their Major or Minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department of Statistics and Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics and Data Science. In many of these cases, the student will need to take additional courses to satisfy the Economics and Statistics major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Economics and Statistics.

Sample Program

The following sample program illustrates one way to satisfy the requirements of the Economics and Statistics Major. Keep in mind that the program is flexible and can support other possible schedules (see footnotes below the schedule).

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
21-120 Differential and Integral Calculus	36-202 Methods for Statistics & Data Science	36-235 Probability and Statistical Inference I	36-236 Probability and Statistical Inference II
36-200 Reasoning with Data	21-256 Multivariate Analysis	73-230 Intermediate Microeconomics	21-240 Matrix Algebra with Applications
73-102 Principles of Microeconomics	73-103 Principles of Macroeconomics		73-240 Intermediate Macroeconomics
15-110 Principles of Computing	-----	73-265 Economics and Data Science	73-274 Econometrics I
	-----	-----	-----

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
36-350 Statistical Computing	36-402 Advanced Methods for Data Analysis	36-3xx or 36-4xx Advanced Data Analysis Elective	36-3xx or 36-4xx Advanced Data Analysis Elective
36-401 Modern Regression		Economics Elective	Economics Elective
73-374 Econometrics II	-----	-----	-----
-----	-----	-----	-----
-----		-----	-----

*In each semester, ----- represents other courses (not related to the major) which are needed in order to complete the 360 units that the degree requires.

Prospective PhD students are advised to add 21-127 fall of sophomore year, replace 21-240 with 21-241, add 21-260 in spring of junior year and 21-355 in fall of senior year.

The Major in Ethics, History, and Public Policy

Professor Steven Schlossman, Director of Ethics, History, and Public Policy, History Department
Location: Baker Hall 236A, 412-268-2880
sls@andrew.cmu.edu

Dr. Alexandra Garnhart-Bushakra, *Academic Program Manager*, History Department
Location: Baker Hall 240, 412-268-2880
agarnhar@andrew.cmu.edu
https://go.oncehub.com/AlexGarnhartBushakra (https://calendar.google.com/calendar/u/0/appointments/schedules/AcZssZ24Bwky_tkdT8oSWDK0w6cwg1GvEhFDegMNcZPEEmtJ8IILU5DHrd0EVab-VLXcmKjZUc8-Jql0/)

Patrick Doyle, *Academic Program Manager*, Philosophy Department
Location: Baker Hall 161G, 412-268-3704
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The B.A./B.S. in Ethics, History, and Public Policy (EHPP) is an interdepartmental major offered jointly by the Departments of History and Philosophy.

Preparing students to be leaders is a vital goal of colleges and universities in every democratic society. The intellectual challenges facing public and private sector leaders have expanded dramatically since the pioneering EHPP program began in 1996, but the need remains as great as ever for broadly educated, ethically sensitive, and technically skilled leaders.

EHPP prepares students to demonstrate sophistication and flexibility in their command of interdisciplinary knowledge; deep historical understanding of how modern-day policy problems have emerged and evolved; and clear, rational criteria for ethical and socially just decision making. The curriculum provides students with a strong humanistic foundation for developing such high-level, historically grounded, and ethically attuned leadership capacities. It also offers ample room for specialization in a wide range of policy areas in which the History and Philosophy departments have special expertise, e.g., medicine and public health, criminal justice, environment, technology, artificial intelligence (AI), gender, civil rights, immigration, and education.

Curriculum

Students seeking a primary major in Ethics, History, and Public Policy may elect to receive either a Bachelor of Arts or a Bachelor of Science degree (additional requirements apply; see below). Basic requirements include 120 units encompassing 45 units in History, 45 units in Philosophy, 18 units in Law and Social Science, and a 12-unit EHPP Capstone Course. This program may also be taken as an additional (i.e., second) major. All courses toward the major must be taken for a letter grade and must be passed with a grade of "C" or better. Students can double count any course for the major with another major or minor, with the exception of Social and Political History, for which a student can double count a maximum of two courses.

I. Foundation Courses in History and Philosophy — 18 units

Choose one of the following two courses:

79-189	Democracy and History: Thinking Beyond the Self	9
79-248	U.S. Constitution & the Presidency	9

Choose one of the following two courses:

80-130	Introduction to Ethics	9
80-330	Ethical Theory	9

II. Ethics and Policy Core — 36 units

Choose four of the courses below:

No more than one course may be taken at the 100 level and at least one course must be taken at the 300 level or above.

80-135	Introduction to Political Philosophy	9
80-136	Social Structure, Public Policy & Ethics	9
80-208	Critical Thinking	9
80-221	Philosophy of Social Science	9
80-234	Race, Gender, and Justice	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-249	AI, Society, and Humanity	9

80-305	Game Theory	9
80-306	Decision Theory	9
80-324	Philosophy of Economics	9
80-330	Ethical Theory	9
80-335	Social and Political Philosophy	9
80-336	Philosophy of Law	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9

III. History and Policy Core 36 units

Choose four of the courses below:

79-175	Moneyball Nation: Data in American Life	9
79-204	American Environmental History	9
79-212	Jim Crow America	9
79-215	Environmental Justice from Conservation to Climate Change	9
79-234	Technology and Society	9
79-242	African American History: Reconstruction to the Present	9
79-248	U.S. Constitution & the Presidency	9
79-250	Voting Rights: An Introduction	9
79-278	How (Not) to Change the World	9
79-300	Controversial Topics in the History of American Public Policy	9
79-320	Women, Politics, and Protest	9
79-321	Documenting Human Rights	9
79-330	Medicine and Society: Health, Healers, and Hospitals	9
79-343	Education, Democracy, and Civil Rights	9
79-360	Crime, Policing, and the Law: Historical and Contemporary Perspectives	9
79-370	Technology in the United States	9
79-380	Hostile Environments: The Politics of Pollution in Global Perspective	9

IV. Foundation Courses in Law and Social Science 18 units

Choose two of the courses below:

17-200	Ethics and Policy Issues in Computing	9
19-101	Introduction to Engineering and Public Policy	12
70-332	Business, Society and Ethics	9
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
84-104	Decision Processes in American Political Institutions	9
84-110	The Economics of Politics, Policy, and Technology	9
84-352	Representation and Voting Rights	9
84-393	Legislative Decision Making: US Congress	9
84-402	Judicial Politics and Behavior	9
88-281	Topics in Law: 1st Amendment	9
88-284	Topics of Law: The Bill of Rights	9

EHPP students will also be able to complete the Foundations of Law and Social Science category by participating in the Washington Semester Program. Students are encouraged to pursue additional policy-relevant courses in law and social science, along lines consistent with their career ambitions.

V. EHPP Capstone Course 12 units

In Fall semester of senior year, EHPP students will participate in an interdisciplinary capstone course that asks students to integrate their studies in Ethics and History by addressing a policy topic of contemporary national urgency (e.g., climate change, immigration, infrastructure, abortion, hate speech, reparations, law enforcement and policing, charter schools, affirmative action, vaccination, taxation, voting rights, global justice). The Departments of History and Philosophy will alternate teaching the EHPP Capstone Course.

79-449	EHPP Capstone Course [cross-listed]	12
80-449	EHPP Capstone Course [cross-listed]	12

VI. Bachelor of Science Option

Students may elect to earn a Bachelor of Science rather than a Bachelor of Arts degree by completing two courses from the list below, or by petitioning the Director of EHPP to accept equivalent courses as substitutions.

21-257	Models and Methods for Optimization	9
36-202	Methods for Statistics & Data Science	9
or 70-208	Regression Analysis	
36-303	Sampling, Survey and Society	9
36-309	Experimental Design for Behavioral & Social Sciences	9
70-257	Optimization for Business	9
80-305	Game Theory	9
80-306	Decision Theory	9
88-221	Markets, Democracy, and Public Policy	9
88-223	Decision Analysis	12
88-251	Empirical Research Methods	9
88-300	Programming and Data Analysis for Social Scientists	9

Additional Major

The B.A./B.S. in Ethics, History, and Public Policy may be scheduled as an additional major in consultation with the Director of Ethics, History, and Public Policy.

Ethics, History, and Public Policy Sample Curriculum

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
Foundations Course in History	Foundations Course in Law and Social Sciences	EHPP Capstone Course	Ethics and Policy Core Course
Foundations Course in Philosophy	Foundations Course in Law and Social Sciences	Ethics and Policy Core Course	History and Policy Core Course
Ethics and Policy Core Course	Ethics and Policy Core Course	History and Policy Core Course	Third Course (open)
History and Policy Core Course	History and Policy Core Course	Fourth Course (open)	Fourth Course (open)
Fifth Course Open	Fifth Course (open)	Fifth Course (open)	Fifth Course (open)

The above sample program is presented as a two-year (junior-senior year) plan for completing EHPP major requirements. Its purpose is to show that this program can be completed in as few as two years; not that it must be.

Students may enter the EHPP major, and begin major course requirements, as early as they wish. Students should consult their advisor when planning their program.

The Major in Information Systems

Joseph S. Mertz, Jr., *Faculty Program Director*
Location: Hamburg Hall 3028, JoeMertz@cmu.edu

Artificial intelligence. Machine learning. Deep learning. Big data. Social networks. Neural networks. Robotics. Automated voice assistants. Blockchain. Driverless vehicles. Web design. Carnegie Mellon University's Information Systems (IS) program (p. 443) will help you do just that. At CMU, Information Systems is a joint degree program between Heinz College and Dietrich College of Humanities and Social Sciences and is strongly technical, drawing from Carnegie Mellon's leadership in computer science, human-centered design, business management, and software engineering. It is deeply rooted in the humanities and social sciences, allowing students the lifelong benefits of a rich liberal arts education. And it provides pathways for students to find their own Information Systems niche through advanced study and exploration with leading researchers.

In addition to General Education Requirements and basic prerequisites in Mathematics and Computer Science, The IS program curriculum includes a broad grounding in humanities and social sciences to promote critical thinking, and interdisciplinary problem-solving, an Information Systems Core to provide business-facing skills needed to design and build effective real-world systems solutions, an Information Systems Breadth focused on professional communications, quantitative analysis, and how technology functions in society, and a concentration that gives you the flexibility and agency to gain expertise in a supporting area and define your own niche in IS.

The IS major is the perfect place for you if you are passionate about using technology for positive gains across society, both economic and humanistic.

For full program information, go to The Major in Information Systems (p. 443).

The Major in Linguistics

Patrick Doyle, *Academic Program Manager*
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Linguistics is the scientific study of human language. The central goal of the Linguistics Major is to provide students with the analytical skills and linguistic concepts needed to understand language scientifically, whether formally, as researchers, or informally, as participants in daily linguistic interactions. The foundation of the Linguistics Major is a set of rigorous core courses, informed by contemporary approaches to the study of linguistic form and meaning.

The **Core courses** cover the principal domains of linguistic analysis: phonetics and phonology, syntax and meaning.

Students then move on to the **Extended Core**, which includes more advanced courses as well as courses on a wider range of topics, such as intonation and language variation. These courses are supplemented by a wide-ranging set of electives including linguistically relevant courses taught in other departments.

Primary majors complete their course of study with a Senior Thesis, a semester-long research project carried out independently with one-on-one guidance from a member of the linguistics faculty.

Curriculum

The Linguistics **primary major** requires a total of 12 courses plus a senior thesis. The Linguistics **additional major** requires a total of 13 courses (senior thesis not required). This includes 2 semesters of sequential language study for all majors. At least three courses (not including specific language courses) must be at the 300-level or higher. All courses counted towards the major must be taken for a letter grade and passed with a grade of "C" or above. Students may double count any course for the major simultaneously with another major or minor.

Linguistics Core (36 units)

Complete the following requirements.

80-180	Nature of Language: An Introduction to Linguistics	9
80-282	Phonetics and Phonology I	9
80-280	Linguistic Analysis	9
or 80-285	Natural Language Syntax	
80-381	Meaning in Language	9
or 80-383	Language in Use	

Extended Core (27 units)

Choose three courses (27 units) from Extended Core and/or additional courses from Linguistics Core.

80-283	It Matters How You Say It	9
80-286	Words and Word Formation: Introduction to Morphology	9
80-287	Language Variation and Change	9
80-288	Intonation: The Meaning of Linguistic Tunes	9
80-382	Phonetics and Phonology II	9
80-384	Linguistics of Turkic Languages	9
80-385	Linguistics of Germanic Languages	9
80-388	Linguistic Typology: Diversity and Universals	9
80-488	Acoustics of Human Speech: Theory, Data, and Analysis	9

LANGUAGE REQUIREMENT

Students must successfully complete 2 semesters of foreign language study in a single language (e.g. 100 & 200 level).

Electives

Primary majors choose **three** additional electives (27 or more units).
Additional majors choose **four** additional electives (36 or more units).
Primary majors: see thesis requirement below.

These Electives can be additional courses from the Core or Extended Core courses listed above, the electives list below, or any other course which is approved by the Academic Program Manager as a linguistics elective. Listed below are the additional electives taught on a regular basis. Additional appropriate courses are offered irregularly or on a one-off basis. The Academic Program Manager will provide students with a list of possible electives each semester, and will assist students in selecting electives which are consistent with their goals and interests.

Philosophy		
80-484	Language and Thought	9
English		
76-318	Communicating in the Global Marketplace	9
76-325	Intertextuality	9
76-385	Introduction to Discourse Analysis	9
76-386	Language & Culture	9
76-388	Coding for Humanists	9
76-389	Rhetorical Grammar	9
Modern Languages		
82-239	Crazy Linguistically Rich Asian Languages	9
82-304	French & Francophone Sociolinguistics	9
82-305	French in its Social Contexts	9
82-334	Structure of Chinese	9
82-585	Topics in Second Language Acquisition	9
82-373	Structure of the Japanese Language	9
82-383	Second Language Acquisition: Theories and Research	9
82-388	Topics in Second Language Acquisition	9
Psychology		
85-354	Infant Language Development	9
85-421	Language and Thought	9
Language Technologies Institute		
11-411	Natural Language Processing	12
11-423	ConLanging: Lrng. Ling. & Lang Tech via Constru Artif. Lang.	12
11-492	Speech Technology for Conversational AI	12
11-422	Grammar Formalisims	12

Note: all 11-xxx courses have significant Computer Science prerequisites. Interested students should check with the course instructor and with the Linguistics Academic Program Manager before registering.

Statistics and Data Science		
36-468	Special Topics: Text Analysis	9

SENIOR THESIS [PRIMARY MAJORS ONLY]

Primary majors must complete a senior thesis (a workload equivalent to a 12-unit course) 80-595 Senior Thesis. Topics must be approved by an advisor, who will work with the student and guide the thesis project. Students are responsible for identifying their topic and securing their thesis advisor. Students should work with the Academic Program Manager of the major to begin the process of identifying their thesis topic and advisor during the fall of their senior year at the latest. Students will be required to submit a written proposal of their thesis project, signed by their thesis faculty advisor, before the end of the semester preceding that in which the thesis research will be conducted..

Additional Major in Linguistics

The Linguistics additional major requires a total of 13 courses. This includes 2 semesters of language study for all majors. At least three courses (not including specific language courses) must be at the 300-level or higher. Additional majors are not required to write a thesis but must take four electives (36 or more units). All courses counted towards the major must be taken for a letter grade and passed with a grade of "C" or above. Students may double count any course for the major simultaneously with another major or minor. If you are interested in obtaining an additional major in Linguistics, please reach out to the Academic Program Manager, Philosophy Department.

The Major in Psychology and Biological Sciences

This unified major is intended to reflect the interdisciplinary nature of our current research in the fields of psychology and biology, as well as the national trend in some professions to seek individuals broadly trained in both the social and natural sciences. Students entering from the Dietrich College of Humanities and Social Sciences will earn a Bachelor of Science in Psychology and Biological Sciences. Students entering from the Mellon College of Sciences receive a Bachelor of Science in Biological Sciences and Psychology.

Pre-Major Requirements

The unified major specifies particular pre-major requirements in the areas of mathematical sciences and statistics, natural science, and computational reasoning. Particular courses are specified in these areas because they are prerequisites for courses required in the major and therefore they are the most efficient way to complete the general education requirements for either Dietrich College or SHS. All other general education categories can be filled in any way that satisfies the requirements of the student’s college or of the SHS program.

The major in Psychology and Biological Sciences is offered only as a B.S. degree. Full curriculum requirements can be viewed under the Department of Psychology (p. 478) section of the Catalog.

Student-Defined Major Program

Joseph E. Devine, *Director and Associate Dean for Undergraduate Studies*
Location: Baker Hall 154F
jd0x@andrew.cmu.edu
www.cmu.edu/dietrich/academics/degrees-majors-minors/student-defined-majors.html (https://www.cmu.edu/dietrich/academics/degrees-majors-minors/student-defined-majors.html)

For Dietrich College students whose educational goals cannot be as adequately served by the curricula of existing majors, the college offers the opportunity to self-define a major. The procedure for establishing such a major centers on a written proposal, submitted to the Dietrich College Dean's Office. This proposal consists of two parts:

Major Description and Rationale

A description of the components of the proposed program of study; a presentation of the objectives of the program of study, how it represents a coherent and (given available faculty, courses, and other resources) viable course of study, and the reason(s) why these objectives cannot be accomplished within one or more of the college's existing majors.

Curriculum

Presentation of a complete outline of all courses that will comprise the requirements for the major. These courses should be categorized in two ways: first, according to that component of the major program to which each belongs (e.g., mathematical prerequisites; research methods; theoretical perspectives; etc.); and second, a semester-by-semester outline that indicates when each course is to be taken (or, for any already taken, when taken and grade received). In addition to courses taken at Carnegie Mellon, the major's curriculum may include courses taken (or to be taken) at other schools, related projects or internships, or programs of study abroad. The minimum requirements for graduation is, as with all majors in the college, 360 units of credit and completion of the Dietrich College general education program.

Proposals and curricula are evaluated for clarity of focus, coherence and depth in related areas, and viability. Proposals should generally be developed no later than the sophomore year, and approved majors begin their program generally no later than the junior year.

The student-defined option is also possible to propose as an additional major or minor. These options extend to undergraduates from all Carnegie Mellon colleges.

Dietrich College Interdisciplinary Minors

Dietrich College interdepartmental minors are programs whose content and components span two or more academic departments to form coherent patterns of study.

A number of interdepartmental minors are offered by Dietrich College and are, in general, available to all Carnegie Mellon undergraduate students. As well, there are numerous other minors offered by other colleges in the university that are generally available to Dietrich College students. The full list of minors available to Carnegie Mellon students is located in the catalog index under “Minors.”

Completion of the requirements for any of these minors is noted on the final transcript.

To declare a Dietrich College interdepartmental minor, students should contact the college's Academic Advisory Center (AAC) and the faculty advisor for that minor.

To discuss the possibility of declaring a non-Dietrich College minor, contact the advisor listed for the minor in question.

In general, unless noted, no course taken to fulfill requirements for these interdepartmental minors may apply toward any other program's requirements.

The Minor in African and African American Studies

Professor Edda L. Fields-Black, *Faculty Advisor,* History Department
Location: Baker Hall 231B, 412-268-8012
fieldsblack@andrew.cmu.edu

Dr. Alexandra Garnhart-Bushakra, *Academic Program Manager*, History Department
Location: Baker Hall 240, 412-268-2880

Mission

The African and African American Studies minor introduces students to several large regions of the world: sub-Saharan Africa, the Americas, and the Caribbean. Broad geographic coverage and a comparative framework encourage students to make connections between Africa and the African Diaspora, as well as among different Diasporan communities. The minor offers undergraduates the opportunity to undertake an empirical and theoretical examination of the cultural, political, social, and historical experiences of Africans and people of African descent.

This unique transnational minor brings together several departments and colleges within the university and allows students to develop analytical skills particular to the arts, humanities, social sciences, public policy, and management. The African and African American Studies minor allow students a considerable degree of freedom in their choice of electives and independent research projects, including opportunities to study and conduct research in a relevant foreign language.

Courses taken to fulfill requirements in other major or minor programs may only be applied to this minor with permission of the Faculty Advisor.

Requirements

- The minor is composed of 54 units - two core courses and four elective courses.
- The elective courses must include one course that requires a research paper or project.
- Students may take an additional two core courses as electives, but not more than four total courses.
- Students must take courses in at least two of the four regions (African, African American, Latin American, and the Caribbean) between their core and elective courses.

Core Courses — 18 units

Choose two from the History and/or English Department courses listed below:

African		
79-226	African History: Earliest Times to 1780	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
African American		
76-232	Introduction to Black Literature	9
79-242	African American History: Reconstruction to the Present	9

Elective Courses — 36 units

African		
79-225	West African History in Film	9
79-237	Comparative Slavery *	9
79-290	The Slave Passage: From West Africa to the Americas	9
79-385	Out of Africa: The Making of the African Diaspora *	9
82-303	French & Francophone Cultures	9
82-304	French & Francophone Sociolinguistics **	9
African American		
57-480	History of Black American Music	6
76-407	Topics in Literary & Cultural Studies : There Are Black People in the Future	9
79-237	Comparative Slavery *	9
79-247	African Americans, Imprisonment, and the Carceral State	9
79-252	"Harriet": Harriet Tubman, Slavery, and the Underground Railroad	6
79-333	African Americans, Race, and the Fight for Reparations	9
79-371	African American Urban History	9
Caribbean		
79-237	Comparative Slavery *	9
79-385	Out of Africa: The Making of the African Diaspora *	9
82-303	French & Francophone Cultures	9
82-304	French & Francophone Sociolinguistics **	9
Latin American		
79-317	Art, Anthropology, and Empire	9
82-343	Latin America Language and Culture	9
82-451	Studies in Latin American Literature and Culture	9

Notes:

* Denotes courses that require a research paper/project.

** Denotes courses taught in a foreign language

The Minor in Film and Media Studies

Laura E. Donaldson, *Academic Advisor*
Jeffrey Hinkelman, *Faculty Advisor*

Location: Department of English, Baker Hall 259

Film and the electronic media are a crucial part of contemporary culture and society; they constitute an important tool for under-standing social arrangements, historical changes, and play an increasingly important role in the development of aesthetic and cultural theory. The Dietrich College minor in Film and Media Studies offers students the opportunity to engage with film and visual media, from theoretical framing and historical-cultural contextualization to training skills in both creating and analyzing film, as well as the development of a complex blend of creative, professional, and technical competencies.

A maximum of two courses may double count with other programs.

The courses listed below are offered with at least general regularity. Participating departments may subsequently develop and offer other courses that, while not listed here, are deemed appropriate for this minor. A faculty advisor for the minor should be consulted (especially when the schedule of courses to be offered for a given semester becomes available) to identify such additional courses.

Required Introductory Course 9 units

76-239	Introduction to Film Studies (prerequisite for 76-439)	9

Required Intermediate Course 9 units

76-310	Advanced Studies in Film and Media	9

Film and Media Electives 27 units

Complete a minimum of 27 units of course work at the 200-level or above when the primary topic is film and media. Courses may include, but are not limited to, the following:

54-191	Acting for Non-Majors	9
76-259	Film History	9
76-269	Introduction to Screenwriting	9
76-292	Introduction to Film Production	9
76-295	Russian Cinema: From the Bolshevik Revolution to Putin's Russia	9
76-312	Crime and Justice in American Film	9
76-313	Creative Visual Storytelling in Film Production	9
76-339	Topics in Film and Media *	9
76-353	Transnational Feminisms: Fiction and Film	9
76-367	Fact Into Film: Translating History into Cinema	9
76-374	Mediated Narrative	9
76-439	Seminar in Film and Media Studies	9
76-448	Shakespeare on Film	9
76-454	Rise of the Blockbuster	9
76-456	Independent Study in Film & Media Studies (requires prior approval)	Var.
76-469	Screenwriting Workshop	9
79-220	Screening Mexico: Mexican Cinema, 1898 to Present	6
79-306	Fact into Film: Translating History into Cinema	9
79-308	Crime and Justice in American Film	9
79-309	The Chinese Revolution Through Film (1949-2000)	9
79-319	India Through Film	6
79-340	Juvenile Delinquency & Film: From "Boyz N the Hood"(1991) to "The Wire"(2002-08)	6
82-215	Arab Culture Through Dialogues, Film, and Literature	9
82-278	Japanese Film and Literature: The Art of Storytelling	9
82-296	From Augustine to Avatars: Personal Narratives Across Media	6
82-362	Italian Language and Culture II (if significant portion of course pertains to film)	9
82-253	Korean Culture Through Film	9
82-428	History of German Film	9
82-456	Topics in Hispanic Studies (if significant portion of course pertains to film)	9
82-533	Cultural Topics in Chinese Studies (if significant portion of course pertains to film)	6

* May be taken up to three times and counted for additional credit toward Film and Media Electives if topics differ.

Students should consult with a faculty advisor for the minor regarding courses not listed above.

400-level Film and Media Course 9 units

Complete one 400-level course from the Department of English that concentrates on film/media directly or that uses it as a tool of social or cultural analysis.

76-439	Seminar in Film and Media Studies	9
76-448	Shakespeare on Film	9
76-454	Rise of the Blockbuster	9
76-456	Independent Study in Film & Media Studies (requires prior approval)	Var.
76-467	Crime Fiction and Film	9
76-469	Screenwriting Workshop	9

The Minor in Gender Studies

Lisa Tetrault, *Professor of History and Faculty Advisor*
tetrault@andrew.cmu.edu
Location: English Department, Baker Hall 259

Gender studies is an interdisciplinary field that investigates how gender is embedded in social, cultural, and political relationships. It understands gender as a category of power that intersects with other power relations, including race, class, and sexuality.

Courses allow students to develop a deeper understanding of how gender operates, and to transfer the analytical skills they acquire to other courses as well as to their personal and professional lives. The minor combines coursework in some combination of the following fields: English, history, anthropology, psychology, philosophy, economics, and modern languages.

Courses listed are only examples. Course offerings change regularly, so please consult semester offerings and the minor advisor for other courses.

The courses listed below are offered with at least general regularity. Participating departments may develop and offer other courses that, while not listed here, are appropriate for the study of gender. Consult the minor advisor to confirm the relevance of unlisted, gender-focused courses.

Complete 1 of the following required courses. 9 units

76-241	Introduction to Gender Studies	9
79-320	Women, Politics, and Protest	9
79-331	Body Politics: Women and Health in America	9

Complete 5 or more additional courses totaling at least 45 units. 45 units

See examples below, but other courses may fulfill this requirement.*

76-353	Transnational Feminisms: Fiction and Film	9
79-244	Women in American History	9
79-320	Women, Politics, and Protest **	9
79-323	Making Modern Cities	9
79-324	#MeToo: Naming and Resisting Gender Violence	6
79-325	U.S. Gay and Lesbian History	6
79-331	Body Politics: Women and Health in America **	9
82-300	Language & Society in the Arab World	9
84-312	Terrorism in Sub-Saharan Africa	6
85-350	Psychology of Prejudice	9
85-446	Psychology of Gender	9

* Consult with Gender Studies Minor Advisor Professor Lisa Tetrault at tetrault@andrew.cmu.edu.
** If not taken as a requirement.

Minor in Health Care Policy and Management

Sponsored by:
Heinz College of Information Systems and Public Policy
Dietrich College of Humanities and Social Sciences
Mellon College of Science

Faculty Advisors:
Jason D'Antonio, Mellon College of Science
James F. Jordan, H. John Heinz III College

The face of health care is changing. The practice of medicine is being fundamentally altered by the forces of change in public policy, health care organizations and in the industry as a whole. The role of individual professionals in this industry is changing as rapidly as the industry itself. Traditional career paths have disappeared overnight to be replaced by new opportunities that require new skills. New organizations are placing new demands on their professional and medical staffs. The criteria of efficiency and financial stability are entering the domains of diagnosis and treatment.

This minor is designed to provide students considering a career in the health professions with an understanding of how these changes are likely to affect their careers. Students will become familiar with the critical policy and management issues and will begin to learn to operate effectively in the emerging health care environment. The curriculum combines economic, organizational, managerial, historical and psychological perspectives on these issues to provide a foundation for a deepened understanding of the changing structure of health care organizations and policy.

Required Courses for HCPM Minor

A total of 54 units are required to complete this minor. Entry into the minor requires completion of 73-102 Principles of Microeconomics or the equivalent by approval.

Required Courses

Complete a total of 21 units from the following:		
79-330	Medicine and Society: Health, Healers, and Hospitals	9
90-436	Health Systems	6
90-472	Health Policy	6

Elective Courses

Complete a minimum of 24 units from these two sections:

Heinz College Courses		
94-409	Healthcare Information Systems	12
73-328	Health Economics	12
90-832	Health Law	6
90-433	Population Health	6
90-834	Health Care Geographical Information Systems	12
Other courses as approved		

Humanities and Social Sciences Courses (9 units each)		
80-245	Medical Ethics	9
76-494	Healthcare Communications	9
88-365	Behavioral Economics and Public Policy	9
42-444	Medical Devices	9
Other courses as approved		

Please note that some of these courses have prerequisites that will not count toward the completion of the requirements for this minor.

Elective Focus Areas

Focus areas are suggested groupings of electives based on student interest. Students *do not* need to take all electives within one focus area; they are free to choose their 18-unit elective minimum from any combination of focus areas.

Health Management/Administration Focus		Units
90-832	Health Law	6
80-245	Medical Ethics	9
76-494	Healthcare Communications	9

Health Policy Focus		Units
73-328	Health Economics	12
90-832	Health Law	6
90-433	Population Health	6
88-365/90-882	Behavioral Economics and Public Policy	9
Other courses as approved		

Health Analytics & IT Focus		Units
94-409	Healthcare Information Systems	12
90-834	Health Care Geographical Information Systems	12
42-444	Medical Devices	9
Other courses as approved		

The Minor in Linguistics

Linguistics is the scientific study of human language. The central goal of the Linguistics Program is to provide students with the analytical skills and linguistic concepts needed to understand language scientifically, whether formally, as researchers, or informally, as participants in daily linguistic interactions. The foundation of the Linguistics Minor is a set of rigorous core courses, informed by contemporary approaches to the study of linguistic form and meaning. The Core courses cover the principal domains of linguistic analysis: phonetics and phonology, syntax, and meaning. Students then move on to the Extended Core, which includes more advanced courses as well as courses on a wider range of topics, such as intonation and language variation. All courses counted towards the minor must be taken for a letter grade and passed with a grade of "C" or above.

Core (27 units)

Required		
80-180	Nature of Language: An Introduction to Linguistics	9

Select 2 from the following 3 options		
80-282	Phonetics and Phonology I	9
80-280	Linguistic Analysis	9
or 80-285	Natural Language Syntax	
80-381	Meaning in Language	9
or 80-383	Language in Use	

Extended Core: Choose 3 courses (27 units) from the Extended Core and/or additional courses from Core.

Extended Core		
80-283	It Matters How You Say It	9
80-286	Words and Word Formation: Introduction to Morphology	9
80-287	Language Variation and Change	9
80-288	Intonation: The Meaning of Linguistic Tunes	9
80-382	Phonetics and Phonology II	9
80-384	Linguistics of Turkic Languages	9
80-385	Linguistics of Germanic Languages	9
80-388	Linguistic Typology: Diversity and Universals	9
80-488	Acoustics of Human Speech: Theory, Data, and Analysis	9

The Minor in Logic and Computation

The Minor in Logic and Computation provides students with general course work in logic, the theory of computation, and philosophy. Students must complete six courses, among them the following three core courses. All courses counted towards the minor must be taken for a letter grade and passed with a grade of "C" or above.

Logic and Computation Core Courses — 27 units

80-150	Nature of Reason	9
80-211	Logic and Mathematical Inquiry	9
or 80-210	Logic and Proofs	
80-310	Formal Logic	9
or 80-311	Undecidability and Incompleteness	

Logic and Computation Electives — 27 units

Students must take two courses in the Philosophy Department at the 300-level or higher, in subjects related to logic and computation. And an additional course at the 300-level or higher in an area that uses logical and computational tools, such as philosophy, computer science, linguistics, mathematics, psychology, or statistics. The choice of electives must be approved by the Academic Program Manager.

Neural Computation Minor

Dr. Tai Sing Lee, *Director*
Melissa Stupka, *Administrative Coordinator*
https://www.cmu.edu/ni/academics/minor-in-neural-computation.html

Neural computation is a scientific enterprise to understand the neural basis of intelligent behaviors from a computational perspective. Study of neural computation includes, among others, decoding neural activities using statistical and machine learning techniques, and developing computational theories and neural models of perception, cognition, motor control, decision-making and learning. The neural computation minor allows students to learn about the brain from multiple perspectives, and to acquire the necessary background for graduate study in neural computation. Students enrolled in the minor will be exposed to, and hopefully participate in, the research effort in neural computation and computational neuroscience at Carnegie Mellon University.

The minor in Neural Computation is an intercollege minor jointly sponsored by the School of Computer Science, the Mellon College of Science, and the Dietrich College of Humanities and Social Sciences, and is coordinated by the Neuroscience Institute (https://www.cmu.edu/ni/) and the Center for the Neural Basis of Cognition (CNBC) (http://www.cnbc.cmu.edu/).

The Neural computation minor is open to students in any major of any college at Carnegie Mellon. It seeks to attract undergraduate students from computer science, psychology, engineering, biology, statistics, physics, and mathematics from SCS, CIT, H&SS and MCS.

The Neural Computation minor is open to students in any major of any college at Carnegie Mellon. It seeks to attract undergraduate students from computer science, psychology, engineering, biology, statistics, physics, and mathematics from SCS, CIT, Dietrich College and MCS. The primary objective of the minor is to encourage students in biology and psychology to take computer science, engineering and mathematics courses, to encourage students in computer science, engineering, statistics and physics to take courses in neuroscience and psychology, and to bring students from different disciplines together to form a community. The curriculum and course requirements are designed to maximize the participation of students from diverse academic disciplines. The program seeks to produce students with both basic computational skills and knowledge in cognitive science and neuroscience that are central to computational neuroscience.

APPLICATION

Students must apply for admission no later than November 30 of their senior years; an admission decision will usually be made within one month. Students are encouraged to apply as early as possible in their undergraduate careers so that the director of the Neural Computation minor can provide advice on their curriculum, but should contact the program director any time even after the deadline.

To apply, send email to the director of the Neural Computation minor Dr. Tai Sing Lee (tai@cnbc.cmu.edu) and copy Melissa Stupka (mstupka@andrew.cmu.edu). Include in your email:

- Full name
- Andrew ID
- Preferred email address (if different)
- Your class and College/School at Carnegie Mellon
- Semester you intend to graduate
- All (currently) declared majors and minors
- Statement of purpose (maximum 1 page) – Describes why you want to take this minor and how it fits into your career goals
- Proposed schedule of required courses for the Minor (this is your plan, NOT a commitment)
- Research projects you might be interested in

Curriculum

The Minor in Neural Computation will require a total of five courses: four courses drawn from the four core areas (A: neural computation, B: neuroscience, C: cognitive psychology, D: intelligent system analysis), one from each area, and one additional depth elective chosen from one of the core areas that is outside the student’s major. The depth elective can be replaced by a one-year research project in computational neuroscience. No more than two courses can be double counted toward the student’s major or other minors. However, courses taken for general education requirements of the student’s degree are not considered to be double counted. A course taken to satisfy one core area cannot be used to satisfy the course requirement for another core area. The following listing presents a set of current possible courses in each area. Other computational neuroscience courses are being developed at Carnegie Mellon and University of Pittsburgh that will also satisfy core area A requirement and the requirements will be updated as they come on-line. Substitution is possible but requires approval.

A. Neural Computation

		Units
15-386	Neural Computation	9
15-387	Computational Perception	9
15-883	Computational Models of Neural Systems	12
85-419	Introduction to Parallel Distributed Processing	9
86-375	Computational Perception	9
Pitt-Mathematics-1800 Introduction to Mathematical Neuroscience		9

B. Neuroscience

03-362	Cellular Neuroscience	9
03-363	Systems Neuroscience	9
03-365	Neural Correlates of Learning and Memory	9
42-630	Introduction to Neural Engineering (crosslisted with 18-690)	12
85-765	Cognitive Neuroscience	9
Pitt-Neuroscience 1000 Introduction to Neuroscience		9

C. Cognitive Psychology

85-211	Cognitive Psychology	9
85-213	Human Information Processing and Artificial Intelligence	9
85-412	Cognitive Modeling	9
85-419	Introduction to Parallel Distributed Processing	9
85-426	Learning in Humans and Machines	9
85-765	Cognitive Neuroscience	9

D. Intelligent System Analysis

10-301	Introduction to Machine Learning	12
or 10-315	Introduction to Machine Learning (SCS Majors)	
15-281	Artificial Intelligence: Representation and Problem Solving	12
15-386	Neural Computation	9
15-387	Computational Perception	9
15-494	Cognitive Robotics: The Future of Robot Toys	12
16-299	Introduction to Feedback Control Systems	12
16-311	Introduction to Robotics	12
16-385	Computer Vision	12
18-290	Signals and Systems	12
24-352	Dynamic Systems and Controls	12
36-225	Introduction to Probability Theory	9
36-401	Modern Regression	9
36-410	Introduction to Probability Modeling	9
42-631	Neural Data Analysis	12
42-632	Neural Signal Processing	12
86-375	Computational Perception	9
86-631	Neural Data Analysis	12

Prerequisites

The required courses in the above four core areas require a number of basic prerequisites: basic programming skills at the level of 15-110 Principles of Computing and basic mathematical skills at the level of 21-122 Integration and Approximation or their equivalents. Some courses in Area D require additional prerequisites. Area B Biology courses require, at minimum, 03-121 Modern Biology. Students might skip the prerequisites if they have the permission of the instructor to take the required courses. Prerequisite courses are typically taken to satisfy the students' major or other requirements. In the event that these basic skill courses are not part of the prerequisite or required courses of a student's major, one of them can potentially count toward the five required courses (e.g. the depth elective), conditional on approval by the director of the minor program.

Research Requirements (Optional)

The minor itself does not require a research project. The student however may replace the depth elective with a year-long research project. In special circumstances, a research project can also be used to replace one of the five courses, as long as (1) the project is not required by the student's major or other minor, (2) the student has taken a course in each of the four core areas (not necessarily for the purpose of satisfying this minor's requirements), and (3) has taken at least three courses in this curriculum not counted toward the student's major or other minors. Students interested in participating in the research project should contact any faculty engaged in computational neuroscience or neural computation research at Carnegie Mellon or in the University of Pittsburgh. A useful webpage that provides listing of faculty in neural computation is https://www.cmu.edu/ni/academics/pnc/pnc-training-faculty.html. The director of the minor program will be happy to discuss with students about their research interest and direct them to the appropriate faculty.

Fellowship Opportunities

The Program in Neural Computation (PNC) administered by the Center for the Neural Basis of Cognition currently provides 3-4 competitive full-year fellowships ($11,000) to Carnegie Mellon undergraduate students to carry out mentored research in neural computation. The fellowship has course requirements similar to the requirements of the minor. Students do not apply to the fellowship program directly. They have to be nominated by the faculty members who are willing to mentor them. Therefore, students interested in the full-year fellowship program should contact and discuss research opportunities with any CNBC faculty at Carnegie Mellon or University of Pittsburgh working in the area of neural computation or computational neuroscience and ask for their nomination by sending email to Dr. Tai Sing Lee, who also administers the undergraduate fellowship program at Carnegie Mellon. See www.cnbc.cmu.edu/training/undergraduate/undergraduate-research-fellowships-in-computational-neuroscience/ (http://www.cnbc.cmu.edu/training/undergraduate/undergraduate-research-fellowships-in-computational-neuroscience/) for details.

The Program in Neural Computation also offers a summer training program for undergraduate students from any U.S. undergraduate college. The students will engage in a 10-week intense mentored research and attend a series of lectures in neural computation. See www.cnbc.cmu.edu/training/undergraduate/summer-undergraduate-research-program-in-computational-neuroscience/ (http://www.cnbc.cmu.edu/training/undergraduate/summer-undergraduate-research-program-in-computational-neuroscience/) for application information.

The Minor in Rationality, Uncertainty, and Choice: Formal Methods

Core Requirements

Complete all of the following:		Units
80-305	Game Theory	9
80-306	Decision Theory	9
88-223	Decision Analysis	12
or 88-312	Decision Models and Games	

Note: Students must complete three elective courses from the following two categories and must complete at least one course in each category.

Elective Category 1: Formal Foundations 9-18 units

80-201	Knowledge and Justified Belief	9
80-208	Critical Thinking	9
80-210	Logic and Proofs	9
80-315	Logics for Knowledge and Belief	9
80-325	Foundations of Causation and Machine Learning	9
80-516	Causality and Machine Learning	9
80-521	Seminar on Formal Epistemology: Belief and Evidence	9
80-524	Topics in Formal Epistemology: Topological Philosophy of Science	9
88-223	Decision Analysis	12
88-312	Decision Models and Games	9
88-379	Data-Driven Decision Analysis	9

Elective Category 2: Theory and Applications 9-18 units

80-246	Moral Psychology	9
80-249	AI, Society, and Humanity	9
80-252	Kant	9
80-255	Pragmatism: Making Ideas Work	9
80-261	Experience, Reason, and Truth	9
80-324	Philosophy of Economics	9
80-330	Ethical Theory	9
80-335	Social and Political Philosophy	9

The Minor in Religious Studies

Professor Allyson Creasman, *Faculty Advisor,* History Department
Location: Baker Hall 242D, 412-268-9832
acreasman@cmu.edu

Dr. Alexandra Garnhart-Bushakra, *Academic Program Manager*, History Department
Location: Baker Hall 240, 412-268-2880

The Religious Studies minor offers students a range of intellectual tools for thinking about religious ideas, behaviors and institutions. It also enables students to build a base of knowledge that extends beyond any one particular religious tradition.

Curriculum 54 units

The minor consists of six courses, totaling at least 54 units. Courses taken to fulfill requirements in other major or minor programs may only be applied to this minor with permission of the Faculty Advisor.

Religious Studies minors must satisfy the requirements listed below:

Required Core Course 9 units

All Religious Studies minors are required to take 79-281, Introduction to Religion. This required course introduces several modes of inquiry into religion, such as the philosophy of religion, sociological and behavioral approaches to religion, historical analysis of religious subject, literary and critical analysis of religious texts, theological modes of thought, and anthropological treatments of religion. This course is offered regularly, usually in the Spring semester.

79-281	Introduction to Religion	9

Distribution Requirements 18 units

In addition to the required Core Course, students must complete Distribution Courses totaling 18 units (usually two 9-unit courses). A Distribution Course is one that applies a particular discipline to more than one religion. Some examples of qualifying Distribution Courses that have been offered include:

Historical Approaches		
79-208	Witchcraft and Witch-Hunting	9
79-352	Christianity Divided: The Protestant and Catholic Reformations, 1450-1650	9

Philosophical Approaches		
80-276	Philosophy of Religion	9

Textual Approaches

In addition to the courses listed above, participating departments often offer other courses that may qualify as Distribution Courses for the minor. The Faculty Advisor should be consulted to identity qualifying courses (especially after the Schedule of Courses for a given semester becomes available).

Elective Courses 27 units

In addition to the required Core Course and the Distribution Courses, students must complete Elective Courses totaling at least 27 units (usually three 9-unit courses). Unlike Distribution Courses, an Elective Course may focus on the study of only one religion (although courses examining more than one religious tradition can also count as Elective Courses if not otherwise used to fulfill the Distribution Requirement).

Some examples of qualifying Elective Courses that have been offered include:

79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-296	Religion in American Politics	6
79-350	Early Christianity	9
79-375	Science & Religion	6

In addition to the courses listed above, participating departments often offer other courses that may qualify as Elective Courses for the minor. The Faculty Advisor should be consulted to identify qualifying courses (especially after the Schedule of Courses for a given semester becomes available).

In addition to courses offered at CMU, relevant courses taken at the University of Pittsburgh, Duquesne University, or other Pittsburgh institutions may count toward the Elective Requirement with the permission of the Religious Studies minor's Faculty Advisor. The option to cross-register for relevant courses at other local institutions allows students some flexibility in meeting the minor's requirements and gives them the opportunity to explore interests in religious subjects that might not otherwise be covered at CMU. Students who wish to cross-register for courses at other institutions should consult with the Faculty Advisor about whether the selected course(s) will meet the minor's Elective Requirement.

The Minor in Science, Technology and Society

Professor Christopher J. Phillips, *Faculty Advisor,* History Department
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cjp1@cmu.edu

Dr. Alexandra Garnhart-Bushakra, *Academic Program Manager*, History Department
Location: Baker Hall 240, 412-268-2880

This minor provides interdisciplinary perspectives on the development and meaning of science and technology in modern society. The core courses enable you to develop a historical and philosophical understanding of the interplay among science, technology, and society. Elective courses enable you to pursue in greater depth and variety subjects and approaches that build on both the core courses and your primary major.

Courses taken to fulfill requirements in other major or minor programs may only be applied to this minor with permission of the Faculty Advisor.

Curriculum 54 units

Core Courses 27 units

Complete one course from each area. Additional courses from the History of Science Core and the History of Philosophy Core may count as electives for the minor.

Area 1. History of Science Core

Take at least 1 course from the list below.

79-160	Introduction to the History of Science	9
79-170	Introduction to Science, Technology, and Society	9
79-175	Moneyball Nation: Data in American Life	9
79-234	Technology and Society	9
79-330	Medicine and Society: Health, Healers, and Hospitals	9
79-370	Technology in the United States	9
79-380	Hostile Environments: The Politics of Pollution in Global Perspective	9

Area 2. Philosophy of Science Core

Take at least 1 course from the list below.

80-220	Philosophy of Science	9
80-221	Philosophy of Social Science	9
80-226	The Nature of Scientific Revolutions	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-249	AI, Society, and Humanity	9

Area 3. Science Core

Take at least 1 course (9 units total) from the following departments: 15-xxx Computer Science, 09-xxx Chemistry, 03-xxx Biological Sciences, 33-xxx Physics

Electives 27 units

Complete three courses from the approved list of elective courses. Courses listed in Areas 1 and 2 may also be taken as electives if not already completed for an Area requirement. To petition for a course not listed to be approved as an elective, contact the Faculty Advisor, cjp1@cmu.edu, directly.

18-482	Telecommunications Technology and Policy for the Internet Age	12
48-448	History of Sustainable Architecture	9
73-427	Sustainability, Energy, and Environmental Economics	9
76-319	Environmental Rhetoric	9
76-395	Science Writing	9
76-425	Rhetoric, Science, and the Public Sphere	9
76-476	Rhetoric of Science	9
76-492	Rhetoric of Public Policy	9
76-494	Healthcare Communications	9
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-204	American Environmental History	9
79-208	Witchcraft and Witch-Hunting	9
79-215	Environmental Justice from Conservation to Climate Change	9
79-246	Industrial America	9
79-283	Hungry World: Food and Famine in Global Perspective	9
79-297	Technology and Work	9
79-302	Killer Robots? The Ethics, Law, and Politics of Drones and A.I. in War	9
79-303	Pittsburgh and the Transformation of Modern Urban America	6
79-331	Body Politics: Women and Health in America	9
79-357	Science and the Body	6
79-368	Un-natural Disasters: Societies and Environmental Hazards in Global Perspective	6
79-372	The Rise and Fall of Pittsburgh Steel	6
80-101	Dangerous Ideas in Science and Society	9
80-150	Nature of Reason	9
80-312	Mathematical Revolutions	9
80-324	Philosophy of Economics	9
84-387	Remote Systems and the Cyber Domain in Conflict	9
85-380	In Search of Mind: The History of Psychology	9

The Minor in Societal & Human Impacts of Future Technologies (SHIFT)

Core Courses (2 courses, 10 to 18 units total)		Units
80-249	AI, Society, and Humanity	9
80-445	Shift Capstone Experience	1-9

Area Courses (6 courses, 54 units total)
Note: Five of the six Area Courses must be taken in different departments

Technology area (18 units)
Courses that build basic technological competence, and teach concepts and frameworks that provide high-level understanding of computational technologies, including their possibilities and limits.

Complete two courses		Units
05-317	Design of Artificial Intelligence Products	12
05-318	Human AI Interaction	12
05-320	Social Web	12
05-452	Service Design	12
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
16-467	Introduction to Human Robot Interaction	12
17-303	Cryptocurrencies, Blockchains and Applications	9
17-313	Foundations of Software Engineering	12
17-331	Information Security, Privacy, and Policy	12
17-333	Privacy Policy, Law, and Technology	9
17-355	Program Analysis	12
36-202	Methods for Statistics & Data Science	9
67-250	The Information Systems Milieux	9
88-300	Programming and Data Analysis for Social Scientists	9

Social & Behavioral Sciences area (18 units)
Courses that teach the concepts and frameworks of social and behavioral sciences (e.g., economics, psychology, sociology), including methods and analyses such as experimental design and quantitative and qualitative data analysis.

Complete two courses		Units
05-413	Human Factors	9
17-224	Influence, Persuasion, and Manipulation Online	9
36-200	Reasoning with Data	9
70-311	Organizational Behavior	9
70-321	Negotiation and Conflict Resolution	9
70-341	Team Dynamics and Leadership	9
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
84-266	Research Design for Political Science	9
84-267	Data Science for Political Science	9
84-369	Decision Science for International Relations	9

Ethics, Policy & Design Area (18 units)
Courses that teach core concepts and frameworks to address and analyze ethical, policy, and design challenges relevant to current and near-future computational technologies.

Complete two courses		Units
05-413	Human Factors	9
08-200	Ethics and Policy Issues in Computing	9
16-161	ROB Seminar: Artificial Intelligence and Humanity	9
17-224	Influence, Persuasion, and Manipulation Online	9
36-200	Reasoning with Data	9
51-173	Human Experience in Design	9
51-241	How People Work	9
51-371	Futures I	4.5
51-373	Futures II	4.5
51-382	Design Center: Design for Social Innovation	9
70-311	Organizational Behavior	9
70-321	Negotiation and Conflict Resolution	9
70-332	Business, Society and Ethics	9
70-341	Team Dynamics and Leadership	9
70-364	Business Law	6
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
79-175	Moneyball Nation: Data in American Life	9
79-234	Technology and Society	9
79-302	Killer Robots? The Ethics, Law, and Politics of Drones and A.I. in War	9
80-130	Introduction to Ethics	9
80-135	Introduction to Political Philosophy	9
80-330	Ethical Theory	9
80-335	Social and Political Philosophy	9
84-266	Research Design for Political Science	9
84-267	Data Science for Political Science	9
84-275	Comparative Politics	9
84-319	Civil-Military Relations	9
84-325	Contemporary American Foreign Policy	9
84-369	Decision Science for International Relations	9
84-370	Nuclear Security & Arms Control	9
84-372	Space and National Security	9
84-373	Emerging Technologies and International Law	9
84-380	US Grand Strategy	9
84-386	The Privatization of Force	9
84-387	Remote Systems and the Cyber Domain in Conflict	9
84-389	Terrorism and Insurgency	9
84-390	Social Media, Technology, and Conflict	9
84-405	The Future of Warfare	9
88-221	Markets, Democracy, and Public Policy	9

The Minor in Sociology

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The Sociology minor introduces the student to central concepts in sociological theory and methods of empirical inquiry needed to broadly understand social behavior, including its structure, history, and dynamics. Students choose among a range of methodological approaches and substantive topic areas including social psychology, work and organizations, social networks, technology and society, medical sociology, and gender and family. Exposure to these topics will help students understand and appreciate the processes by which families, groups, and organizations form and evolve over time; by which individuals affect and are affected by the society in which they live; and by which technology and institutions shape and influence society. This background in empirical tools and social theory will strengthen the student’s ability to pursue graduate studies in sociology, social history, social science, and organizational theory; to begin professional careers involving social analysis, network analysis, data analysis of teams, groups and organizations, social analysis within journalism, political institutions, the government, and online; and to enter the corporate environment with a thorough understanding of organizational activity.

Curriculum 54 units

In addition to the general education requirements of the student's college and the requirements of the student's major, Sociology minors must satisfy the following requirements. The Core courses comprise 18 units of the minor. One course is taken from the Organizations cluster, and one course is taken from the Methodology cluster. The Elective courses comprise 36 units of the minor. Sociology minors should consult with the program advisor to plan a course schedule prior to registration.

NOTE: The core courses are offered regularly; the elective courses are offered with at least general regularity. Participating departments may subsequently develop and offer other courses that, while not listed here, are deemed appropriate for this minor. The program advisor should be consulted (especially when the schedule of courses to be offered for a given semester becomes available) to identify such additional courses.

No more than two courses (18 units) in the Sociology minor may be counted to fulfill any other major or minor's requirements.

Core Courses 18 units

A. Organizations

Complete one course.		
88-140	Introduction to Sociology	9
or 70-311	Organizational Behavior	

B. Methodology

Complete one course.		
36-202	Methods for Statistics & Data Science	9
70-208	Regression Analysis	9
85-310	Research Methods in Cognitive Psychology	9
85-340	Research Methods in Social Psychology	9
88-251	Empirical Research Methods	9
88-252	Causal Inference: from Data to Decisions	9

Elective Courses 36 units

Complete four courses (a minimum of 36 units) from the following list. Two courses (18 units) must be taken from one category to complete the depth requirement. One course (9 units) must be taken from the other category. The remaining course (9 units) may be taken from either category. Appropriate courses offered by the Department of Sociology at the University of Pittsburgh (available during the academic year through cross-registration) may also be included as part of this option. Contact the Sociology program advisor for more information.

1. Sociology of Gender, Family, and Culture		
70-342	Managing Across Cultures	9
70-385	Consumer Behavior	9
76-241	Introduction to Gender Studies	9

79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-320	Women, Politics, and Protest	9
79-331	Body Politics: Women and Health in America	9
79-343	Education, Democracy, and Civil Rights	9
79-377	Food, Culture, and Power: A History of Eating	9
80-245	Medical Ethics	9
80-246	Moral Psychology	9
80-305	Game Theory	9
80-335	Social and Political Philosophy	9
80-348	Health, Human Rights, and International Development	9
84-369	Decision Science for International Relations	9
85-241	Social Psychology	9
85-350	Psychology of Prejudice	9
85-442	Health Psychology	9
85-446	Psychology of Gender	9
88-230	Human Intelligence and Human Stupidity	9
88-231	Thinking in Person vs. Thinking Online	9
88-285	Deconstructing and Dismantling Discrimination	9
88-290	Confessions, Lies, and Gossip	9

2. Sociology of Work, Organizations, and Technology

70-332	Business, Society and Ethics	9
79-275	Introduction to Global Studies	9
88-234	Negotiation: International Focus	9
88-235	Negotiation: Strategies and Behavioral Insights	9
88-255	Strategic Decision Making	9
88-261	Health Policy and Decision Making	9
88-262	Medical Decision Making	9
88-275	Bubbles: Data Science for Human Minds	9
88-341	Team Dynamics and Leadership	9
88-344	Systems Analysis: Environmental Policy	9
88-365	Behavioral Economics and Public Policy	9
88-366	Behavioral Economics of Poverty and Development	9
88-367	Behavioral Economics & Field Experiments in Organizations	9
88-451	Policy Analysis Senior Project	12
88-452	Policy Analysis Senior Project	12

Note: Some courses have additional prerequisites.

Dietrich College Interdisciplinary Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

Dietrich College Interdisciplinary Courses

66-003 Contested Histories: The Israel-Palestine Conflict

Intermittent: 1 unit
Join one of several small groups of students, faculty and staff in discussing Neil Caplan's remarkable book "The Israel-Palestine Conflict: Contested Histories" (Second Edition). There will be six options for book discussion groups, each led by an expert faculty member, taking place in late February and early March. In-person and remote options will be available. Discussions will explore the contested Palestinian and Israeli narratives of events and aim to move readers beyond assigning blame to wrestling with the complexities and contradictions of the conflict. Is there a chance for peaceful resolution? Registered CMU students who attend a discussion group lead by a university expert and a discussion group with Caplan will receive one unit of academic credit.

66-101 Dietrich Introductory Seminar: College & University Success Strategies

Fall: 3 units
This interactive course is designed to help new students transition successfully to academic and student life in the Dietrich College at Carnegie Mellon. Students will explore campus resources and opportunities; their skills, identity, interests, and goals; and strategies for personal and academic success to help them make the most of their Dietrich experience. This course is only available to be taken by first year students in their first semester at Dietrich College.

66-106 Applied Quantitative Social Science I (QSSS students)

Fall: 9 units
The first course in the QSSS core sequence provides a fast-paced introduction to a range of methods in the quantitative social sciences. Organized around a set of case studies, the course introduces the language and methods of empirical research through a combination of seminar-style discussions of academic papers, and hands-on lab work using the statistical software R. Students will replicate results from a high-profile labor market discrimination paper, explore agent-based models of neighborhood segregation, and scrape Wikipedia data to examine imbalances in gender representation. Enrollment restricted to QSSS students.

66-122 DC Grand Challenge First-Year Seminar: Beyond Earth

Spring: 9 units
The aim in the course is to foster in students a planetary perspective, to see Earth in its context of the cosmos and to see humans in their relation to real or possible forms of life in the universe. The obsession with outer space is found among scientists, business people and politicians, in deed and story, in film and even computer games. If we are to fully appreciate the potentials of space, we must also consider the search for intelligent life in its scientific and societal aspects, and investigate how we could adapt our systems of communication to reach species across distances that may be physically insurmountable. This interdisciplinary course will be taught by scholars from distinct cultural and linguistic backgrounds. Course materials will be taken from scientific literature, the history of science, and science fiction. We will explore scientific writing and reasoning, the space race between global powers, space travel and colonization, and the promise and pitfalls of interspecies and interspace communication. A planetary perspective, once achieved, can change the way one sees other inhabitants of this planet - as partners in survival in a universe which sets enormous odds against it, or as unwelcome intruders grasping for scant resources within this thin epidermis of soil, air, and water which surrounds Earth and makes our lives possible.

66-123 DC Grand Challenge First-Year Seminar: Science on Stage

Spring: 9 units
Art and Science and #8212; two fields of study that are most often considered diametrically opposed. Art is frivolous entertainment. Science is hard rational fact. In this Grand Challenge course, we hope to break that supposition or at least examine it in great detail. Specifically, we will use theater to argue that drama can produce challenging, demanding and intelligent work that showcases the impact of science on current discourse. We want to link the two cultures. The word "theater" has the same etymological root as "theory" - both words come from the Greek thea meaning view. This shared origin demonstrates ways we can work to analyze and interpret both fields and show the common ground between these two cultures. As we attend to plays and writing ranging from Tom Stoppards Arcadia and Michael Frayns Copenhagen to Caryl Churchills A Number and Oliver Sacks Man Who Mistook his Wife for a Hat, our class discussions will consider questions that include: Why is science a trend in contemporary theater? Does it reflect on our dependence on technology? What kinds of questions are being asked when science or scientific theory is presented on the stage? Are people attracted to plays about science because of their difficult subject matter or does it does it lack the engagement of popular culture? In addition to integrating humanities and scientific approaches within Dietrich College, this course will utilize the expertise of both individuals in the School of Drama and the producers in the local theater community, and local science writers. Finally, in addition to weekly writing assignments, the course will ask students to produce original dramatic scenes that incorporate scientific exploration which will, ultimately, lead to staged readings of their work.

66-125 DC Grand Challenge First-Year Seminar: Democracy & Data

Fall: 9 units
From gerrymandering to online political ads, data is being used in ways that raise urgent questions about the integrity of democratic elections. But the relationship between democracy and data goes far beyond elections. In a world of constant surveillance, in which vast amounts of data are gathered from our phones, our computers, and from other facets of our lives - and in which new breakthroughs in machine learning and data analytics make such data dramatically more powerful - what does it mean for average citizens to have control over their own lives? What does democracy mean?

66-126 DC Grand Challenge First-Year Seminar: Voting: An American Tradition

Fall: 9 units
This course investigates the sacred American practice of voting, the cornerstone of American democracy, using the 2020 election cycle as our laboratory. The course uses a multi-disciplinary approach, examining the topic from several different perspectives. We'll investigate social movements to expand the vote, the role of technology, game theory, polling, predictions, electoral mapping, social media, the structures of American governance, and more. Questions include: What is the electoral college? Who gets to vote and why? How well is that vote accounted for? How can voting systems be compromised? Why is it so hard to predict who will win? How do people make decisions? How useful are polling and amp; predictions? What disrupts voting? Why is turnout so low? How does money play a role in the election cycle? Why do we vote the way we do? How is social media changing elections? What are global best practices? Did the founders even intend for a mass democracy? (The answer is no!) Many of you will be first-time, eligible voters in one of the most remarkable presidential campaigns in American history. We'll build your skills as new democratic citizens, of this nation or others, and help you make sense of the history-making U.S. news cycle. A note on partisanship: All political viewpoints are welcome in this class. This is a course on how we navigate and account for political difference in a diverse, disparate nation. This is something we'll practice in class, while we will also study that very process across the nation.

66-127 DC Grand Challenge First-Year Seminar: Environmental Justice

Fall: 9 units
Wondering what the "Green New Deal" proposal is about? Does it seem like you have to choose between protecting people and protecting the planet? How does environmentalism connect to struggles over social justice and human rights? This first-year interdisciplinary seminar is an introduction to the Grand Challenge: Environmental Justice. In Giovanna de Chiro's words, the environmental justice movement is working "toward building diverse, dynamic, and powerful coalitions to address the world's most pressing social and environmental crises global poverty and global climate change by organizing across scales and 'seeking a global vision' for healthy, resilient, and sustainable communities." In this seminar, we'll study the history and science behind two interconnected challenges for environmental justice: global climate change and fine-particulate air pollution. Both types of pollution start with combustion of fossil fuels. Particulate air pollution kills roughly 7 million globally each year; these air pollution deaths happen close to the source, with unequal levels of exposure and risk for people according to class and race. Climate change, mostly from carbon dioxide and methane emissions, is spread globally and lasts well beyond our lifetimes, yet the effects are again disproportionately based on class and race. In this course, we'll explore the science, history, ethics, and public perception of these problems, with implications for Pittsburgh and the planet, and for the near- and long-term future.

66-128 DC Grand Challenge First-Year Seminar: Palestinian and Israeli Food Cultures

Spring: 9 units
In a region beset by conflict, how do food cultures allow us to approach cultural intersections and connections? This course is designed to provide students with a historical, cultural, and linguistic understanding of the hybrid nature of Jewish and Arab cultures, and the multiple ethnic contributions to local food cultures in Israel and Palestine. The two instructors, from the fields of Jewish history and Arabic Studies, will introduce students to the history, literature, film, and languages of the region, as well as to critical scholarship on food and foodways in the Palestinian and Israeli context. Students will have the opportunity to engage in cooking either locally or in Philadelphia - subject to travel restrictions - and to learn from Michael Solomonov and Reem Kassis, two award-winning US-based celebrity chefs and authors of Israeli and Palestinian cook books respectively. Throughout the semester we will also host a range of guest speakers who will deliver lectures on our course topic in the classroom and in the community.

66-129 DC Grand Challenge First-Year Seminar: Unreality: Immersive and Spatial Media

Intermittent: 9 units
Virtual news stories and game worlds are accessible by putting on cardboard goggles, theme parks are engineered to provide convincing multisensory experiences, and workforces are reliant on augmented views of factory floors. Immersive and spatial media constitute a suite of emerging technologies that offer the opportunity to expand arts, entertainment, science, design, commercial enterprises and countless other domains in ways that were previously limited to science fiction. The potential for augmented reality to disrupt our current technological ecosystem is tremendous. Many of these technologies are now 50 years old and just starting to enter the commercial realm. As immersive experiences and augmented realities become more integrated into our work and leisure, do we need to worry about the ways that unreality affect our experiences of reality, or our interactions with each other? How do we know that we can trust our senses to tell us what is real? How do we begin to grapple with the ethical, cultural, social, technological, and regulatory implications of this shift?

66-131 DC Grand Challenge First-Year Seminar: Culture, Sports, and Conflict in/and VR

Intermittent: 9 units
Sports have been celebrated for bringing people together; yet, sports have also been a locus of tensions and conflict that most of us only experience from the sidelines. We understand sports, the people, and their cultural impact through the stories that we tell about them in such places as museums, stadium tours, and Halls of Fame as well as in books, documentaries, and podcasts. Through immersive technologies, these stories are brought to life and bring fans to the heart of the action. In this course, students and faculty together will seek to achieve two main objectives: (1) examine ways in which cultural and societal values are reflected in sports and (2) how Virtual Reality (VR) technology can help design experiences that enhance the users awareness of these issues by engaging with these cultural and societal perspectives. We will first unpack sports stories that are squarely situated at the crossroads of sports and culture(s) (e.g., racism, human rights, and the role of government and/in national politics). Then we will explore the role of VR technology to help craft these narratives. Students, then, will discover what it means to write stories for VR experiences. The course will culminate in students designing an immersive experience about a sports conflict of their choice, which will be developed more fully to be displayed in the Askwith Kenner Global Languages and Cultures Room.

66-132 DC Grand Challenge First-Year Seminar: Health in Unhealthy Times

Intermittent: 9 units
We live in times when health is a major global concern, whether we worry about the increase in Covid-19 cases, await our immunization, strive to understand the disproportionate impact of the disease on BIPOC populations, or debate mitigation measuresnot to mention ongoing concerns with common chronic illnesses such as diabetes, cancer, autoimmune disease, depression, anxiety, etc.. Health, or lack thereof, has always been a critical part of the human experience, and it is fundamentally impacted by different human experiences. This seminar will introduce students to the scientific aspects of health, its political and social determinants, ethical constraints, historical roots, as well as to the cultural and communicative skills required to dialogue about health, make decisions, and engage empathically with others in their health stories. We will read and discuss a broad variety of materials from medical science articles to social psychological experimental reports and personal or literary narratives about health. The course is divided into three components: health and preventative behaviors, managing chronic health challenges, and coping with disruptive health experiences. We believe these components can represent a broad array of interest and engage students on a personal level.

66-133 DC Grand Challenge Seminar: We're Not Beyond Race: Race and Identity in America

Intermittent: 9 units
Race matters. How have social institutions and historical factors led to the belief systems and stereotypes that shape how race is experienced in American society, and how do these belief systems affect the way individuals come to view and define themselves and others? This course considers how race and identity affect peoples lived experiences - how they think, feel, and act - in America. In this course, we will examine the structural and systemic origins of the racial status quo, as well as the way that individuals navigate the social and racial landscape of modern-day America. Including insights from psychology, literature, economics, sociology, and history, the course will focus on how race matters at both a societal level and an individual level. We will consider different racial situations throughout American society to understand how individuals navigate and experience race and identity. Throughout the course, we will watch films, read literature, and analyze music and art that reflect the experience of race and identity.

66-134 DC Grand Challenge First-Year Seminar: Native Americas: Facts and Fictions

Intermittent: 9 units
How did Indigenous people respond to the challenges of populating the American hemisphere and creating complex, diverse and dynamic cultures, languages and political entities? How did they survive, adapt to, and resist the conquest and colonization of their lands, and ensuing social and cultural dislocations? How have they resurged politically, culturally, artistically and intellectually in recent years? This course considers the history, experiences, and perspectives of native populations across the Americas. It seeks to reckon with the facts of the Native American experience, while challenging the fictions of stereotypes and narratives that have often relegated Indigenous people to the social and cultural margins of the nations in which they now live. After introducing students to a few of the myriad Indigenous groups of North, Central and South America, we will then survey the implications of the era of European conquest and colonization. Well consider the implications of the rise of new nations in the Americas, as new and intensifying campaigns of violence were unleashed against Indigenous populations. We will consider the rise of Native American civil rights and political and cultural sovereignty movements from the late 20th century forward, as they coalesced into major political challenges to native marginalization and demands for recognition and reparation of historical injustices. Finally, we will explore how contemporary Indigenous artists, authors, and political and social activists are reimagining indigeneity (the condition and experience of being Indigenous) in ways that demonstrate how indigeneity is not a fixed kind of identity, not one that is confined or defined in any way by a static conception of tradition, but rather one that challenges the present and reimagines the future in dynamic and creative ways.

66-135 DC Grand Challenge First-Year Seminar: Designing Better Human-AI Futures

Intermittent: 9 units
This course will explore the societal impacts of artificial intelligence (AI) based decision-making systems, especially focusing on the societal biases they may enhance or reduce. Students will gain a fundamental understanding of how these systems are designed and work, as well as the role of data in mitigating or enhancing biases. The course is multidisciplinary in nature and brings together social scientists, engineers, data scientists, and designers to tackle the grand challenge of dealing with issues of bias and fairness in Human-AI collaborative systems, ranging from the data that is used to train them, to their human creators that are responsible for deciding how they work and get used. Students will investigate policy, technology and societal elements aimed at reducing and mitigating the impact of AI biases that can negatively impact society, especially its vulnerable members.

66-136 DC Grand Challenge First-Year Seminar: Becoming Resilient in Challenging Times

Spring: 9 units
"My heart is in my work" - a phrase that once rang true to many CMU students and remains the motto our institution lives by. But what happens if life has been interrupted by a global pandemic and our hearts suddenly aren't in our work anymore? How do we as a society respond to challenges and struggles that go beyond our daily work routine and encompass threats to our physical and mental health, social interactions, family life, and hobbies and leisure activities? Today, when the "new normal" seems to be lasting forever and we face an unprecedented mental health crisis, how can we address questions of resilience, wellbeing and perseverance in the classroom, both from an academic and a personal point of view? How can we rebuild communities and societies after traumatic and scarring events, communicate and collaborate across disciplines to solve complex problems, and establish a world where we thrive and succeed again? In a more fundamental way, what does it mean to be resilient, and where is the boundary between our own health and wellness and the cultural, societal, or economic expectations around these ideas? To answer these questions, this course will use graphic novels from English-speaking, German-speaking, and Spanish-speaking countries as its core to introduce students to a variety of graphic approaches to the concept of resilience, including from the graphic medicine genre. We will explore mental and physical health and healing in innovative ways to analyze different perspectives on and models for wellbeing. Working comparatively across cultures, the graphic novels in the course will help re-examine and re-define our understanding of wellbeing and health and explore how visual storytelling can drive social change around issues of individual and community resilience.

66-137 DC Grand Challenge Seminar: Causes and Consequences of Health Disparities

Spring: 9 units
Why do some people live well into their nineties while others are more likely to die at an earlier age? The answer to this question can be more complex than one might think. Life expectancy can be influenced by a host of individual and population-level factors. This course is designed to critically examine the social factors research has found to impact individual and population health experiences. This course will introduce students to the multiple approaches to researching the complex problem of health disparities in the United States with particular emphasis on perspectives from the social sciences and humanities. Specifically, students will examine how factors such as socioeconomic status, education, crime, housing, health care and food availability play important roles in the production of disparate health. Students will examine psychological factors that can create disparate health experiences and the impact of such disparities on psychological health. We will address health disparities at the individual and population levels, learning how disparate health experiences are historically and socially produced, and how such disparities produce negative physical and mental health outcomes for individuals and minoritized populations. At the end of the course, students will present a collaborative group project that examines a specific facet of US health disparities and offer a proposed solution. Using a multi- disciplinary perspective, we will challenge students to discover just how important seemly unimportant interpersonal and structural factors can be in explaining health disparities and how important it is for society to take measures to address these disparities.

66-138 DC Grand Challenge First-Year Seminar: Militarizing Freedom Arms in U.S. Culture

Spring: 9 units
This seminar examines the way American culture and politics have utilized the tools, tactics, and values of the military during both war and peacetime. Utilizing several disciplinary perspectives, including history, rhetorical criticism, fictional narrative, and the discourse of public policy, we will consider the different ways that gun culture, military mobilization, veteran affairs, and police power have influenced American society, including how people relate toor fearone another. We will explore some historical roots of the U.S.'s militarized culture, alongside the linguistic, argumentative, and narrative trends that have contributed to urgent democratic issues like police brutality, domestic terrorism, and the rise of the carceral state. This course will address themes and questions such as: - American exceptionalism: Does violence play an extraordinary role in American and culture, in contrast to other nations? What are its historical antecedents? - The escalation of violence in American political culture: Why does political polarization engender violence? Do traditional appeals to "freedom" accelerate such violence? - How has America become a country of prisons and mass incarceration? - Global impacts: How does the U.S.'s militarized political culture impact nations and people beyond its borders?

66-139 DC Grand Challenge Seminar: Reducing Conflict Around Identity and Positionality

Spring: 9 units
Learning to reduce conflict requires understanding positionality and identities, and why and how societies build barriers in their populations. In this interdisciplinary course, students will learn how to talk to each other and strangers about identity: its defining characteristics and how our bias influences our judgments. The social sciences elements will stress Social Identity Theory, bias, stereotypes, and in-groups and out-groups. The humanities elements will include close-reading strategies and incorporate conceptual frameworks from cultural studies, literary studies, and narrative theory. In addition to practicing the methodologies in these two disciplines, students will undertake two projects. In the first project, they will develop and implement a semi-structured interview protocol for their campus peers centered around belonging. In the second project, students will employ close reading techniques to analyze Young Adult novels that address complex questions of identity, isolation, bias, and rejection. Working with one novel and Project 1 data, each team of social sciences, humanities, and data specialists will create a website to highlight inclusive successes and challenges. This final cohesive 'picture' of themes pertaining to feelings of belonging on our campus will help guide the CMU community toward deeper understanding and acceptance practices.

66-140 Grand Challenge Seminar: Equitable Access and Success in Higher Education at CMU

Spring: 9 units
With the Supreme Court poised to rule on affirmative action, the challenge of equitable access to higher education is back in the public spotlight. Carnegie Mellon, as a university that brings together students from a wide variety of backgrounds, serves as a case study for exploring the challenges and opportunities for achieving equitable access and success in higher education. The array of social identities (e.g., race, gender, national origin, etc.) represented on campus creates an environment where students can engage with a diversity of ideas and experiences. However, this same diversity can also present challenges when students are viewed as "equal" (i.e., all the same) rather than as unique individuals with a diverse set of needs and assets (i.e., equity). Using archival materials, students will explore the history of Carnegie Mellon University from its founding to present day, with attention to the composition of its student body, its approach(es) to equitable access (e.g., admission policies), and students' experiences at the university. Through historical and linguistic analyses, students will examine how language about social identities and equitable access changed over time and how those changes may have impacted student experiences and success at CMU. The historical and linguistic focus of this course will be enhanced via guest speakers involved with initiatives related to equitable access and success at CMU as well as via class materials from other disciplines (e.g., educational psychology). During class meetings and guest speaker sessions, students will be expected to engage with ideas and with each other through discussion. Outside of class, students will complete a variety of course assignments, including readings, written assignments, reflections, and a collaborative project.

66-141 DC Grand Challenge Seminar: Freedom of Speech & Academic Freedom

Intermittent: 9 units
This Grand Challenge course offers a comprehensive exploration of the principles, controversies, and significance of Freedom of Speech (FOS) and Academic Freedom (AF). By exploring actual and hypothetical cases, students will analyze the complex dilemmas that arise when we try to balance two interests: maximizing freedom of expression and creating an inclusive, respectful community. By engaging a wide range of disciplinary perspectives and methods of inquiry from philosophy, history, psychology, law, etc., students will examine how different policies and norms impact these competing interests and vice versa. Students will practice informed and constructive dialogue within the seminar to facilitate independent thought, rigorous inquiry, and how to discuss difficult topics productively. Course topics will include: - the rights and responsibilities involved in FOS for both individuals and institutions, - the history and current state of the law with respect to FOS, - the history and state of university policies and practices about AF for research and education, including scholarship, artistic freedom, teaching, in particular trigger warnings, safe spaces, censorship, protest, and controversial outside speakers, - developmental perspectives on how children learn about freedom of expression, - FOS in advertising, media, and social media, including recommendation algorithms. The broader goal is to empower students to become informed, responsible, and productive members of Carnegie Mellon's transformative university community.

66-142 DC 1st Year Seminar: The Mirror of Technology: Biases in Computation & Cognition

Spring: 9 units
The title of the show, Black Mirror, refers to the blank screens of tech devices that reflect back an image of the human user. The image captures some parts of us, say our facial expression, while deemphasizing, distorting or missing others, say the color of our eyes or skin. Further, the reflection is silent about what goes on under the surface in our heads, what we feel, think and value. At the same time, the screen presents a cover for a computational device which, when activated, is massively interconnected with local and global structures around us and with our minds in ways that we do not notice. Can we understand and explain this increasingly symbiotic relation, sometimes healthy, sometimes not? Through active discussion, group work, engaging with local and national experts, and argument and analysis in written work, we will explore the ways in which recent technologies mirror our minds as well as how our minds are impacted by and come to mirror those technologies. We will focus on the idea of bias and a type of informational selectivity we capture as attention. Topics will include: the nature of meaning, thinking and understanding in animals and machines, tests for cognition in artificial systems with focus on recent large language models such as CHAT GPT, biases in cognition and attention in humans and biases in algorithms and the impacts of these on society, the attention economy and the manipulation of our attention therein, and the symbiosis between mind and machine where machines extend our minds. These topics span philosophy, cognitive science and computer science. Our goal will be to acquire the analytical skills needed to help critically engage with and transform this symbiotic relation between mind and machine, moving it systematically towards a virtuous and healthy state.

66-143 DC Grand Challenge Seminar: Realizing Human Rights

Spring: 9 units
This course will introduce first year students to the challenge of protecting and promoting human rights in a world fraught with conflict, political strife, economic exploitation, and environmental hazards. We will focus on how human rights frameworks can be used to make the world more just, equitable, and free. We will begin by discussing the theoretical foundations of human rights and the development of human rights institutions in the 20th century. Students will learn how rights have been constructed through legal action, activism, and treaty negotiations in the past and examine the emergence and contestation of new rights today. We will explore why particular rights frameworks are privileged in some societies but not others. We will then focus on how practitioners investigate and document potential rights violations around the world, including in our own backyard. The instructors bring disciplinary expertise in history, journalism, and data analysis, and the course will feature guest lectures by legal experts and human rights practitioners. Topics covered will include genocide and other war crimes; political repression; economic, social, and cultural rights; environmental rights; migration and refugees; gender identity and sexuality; and indigenous rights. By the end of semester, students will be prepared to propose an action plan to address a specific human rights challenge in a community that they are familiar with. In previous semesters, our students have worked on projects related to deaths in Pennsylvanias jails and prisons in partnership with local organizations, proposed a project to assess human rights violations of migrants at the US/Mexico border, and conducted an international open source investigation of human rights violations using online media and satellite imagery.

66-144 DC Grand Challenge Seminar: In Transit: Exile, Migration, and Culture

Spring: 9 units
The world is currently experiencing the worst refugee crisis since the end of World War II. Large numbers of people are forced from home for political, personal, or racial reasons, and many others leave home because of grinding poverty and need. Conflicts about the mass migration provoked by this crisis have emerged all over the globe, from the United States, Latin America, and Europe, to Africa, the Middle East, Asia, and even Oceania. Writers, filmmakers, and artists have attempted to address the plight of refugees and migrants in their works, and many writers, filmmakers, and other artists are themselves refugees or migrants. Pittsburgh has a unique institution, City of Asylum, whose mission is to assist and advocate for persecuted writers and other artists. It hosts the largest residency program in the world for writers living in exile under threat of persecution or worse: death. The goal of this Grand Challenge Seminar is (1) to familiarize students with todays plight of refugees (e.g., social, political, economic factors; cross-cultural comparisons; dynamics of class, race, gender, and nationality), and (2) introduce them to a variety of textual (literary and theoretical) and visual materials and to the resources available through City of Asylum. Through readings, discussions, guest speakers, short papers, and group film projects/presentations, students will examine the ways in which writers, filmmakers, musicians, and other artists have addressed exile and migration in their work by constructing, revising, and reinventing images and cultures of the homeland. Students will explore a variety of texts (e.g., films, documentaries, art, music, photography; prose, poems, and presentations by exiled artists; archival materials; news reports, articles) and meet with and interview exiled writers and other artists.

66-145 DC First Year Seminar: Appalachia: Development, Decline, and Identity in America

Spring: 9 units
The Appalachian region, which stretches from Georgia to New York's southern tier, has a particular place in American history and memory. This course will examine the political, literary, economic, and historical narratives that surround the region, as well as examining the role that Appalachia can play as a model for developing regions in other parts of the world. The paradoxes of Appalachia have confronted American culture since its first settlement by Europeans in the 18th century: a region of unparalleled biodiversity, it has nevertheless been characterized by ongoing poverty and isolation. Politically, it has given rise to both progressive collective action and conservative rhetoric. Economically, its natural resources have been widely exploited by outside economic and industrial interests. Its inhabitants have been characterized as either fiercely independent or widely dysfunctional, giving rise to the archetypes of Mountaineers, Rednecks, or Hillbillies. Its cultural ethos has resisted ready inclusion into mainstream culture. This course will examine these paradoxes by utilizing history, literature, and public policy documents that detail the ongoing debates surrounding Appalachian development, while consulting with several invited writers, political figures, and artists who have interpreted the regions role in American history.

66-146 DC 1st Year Seminar: From Pandemics to Politics: Modeling Complex Social Systems

Fall: 9 units
TBA

66-147 DC Grand Challenge First-Year Seminar: (Mis)Trust in Research

Fall: 9 units
TBA

66-148 Introduction to Community Engagement

Intermittent: 3 units
This course is designed to prepare students to actively and thoughtfully engage in their community. Students will evaluate various models for community engagement and community-based leadership and examine ethical and social justice issues related to college and university involvement in the community. Through course discussions and direct engagement with community leaders, students will develop the ability to consider multiple perspectives, demonstrate cultural humility and critically reflect to make meaning from experiences. Students will create a plan to infuse community engagement into their academic journey that aligns with their values. This is part of the Dietrich College Community Engagement Fellowship and is only open to students that have been accepted into the program.

66-151 DC Grand Challenge First-Year Seminar: Equity and the Environment

Fall: 9 units
TBA

66-181 Grand Challenge Seminar

Fall and Spring: 9 units
In their firm desire to perfect the new Constitution, which defined and limited the powers and roles of their new government, the founding fathers insisted on explicit statements that would protect the rights of the new nation's citizens. Indeed, the protection of these essential rights in many ways drove and defined their successful rebellion from Britain. This impulse resulted in ten amendments to the Constitution, which we have come to know as the Bill of Rights. The very first (and arguably considered at the time as the most essential) of these was the First Amendment, which we sometimes call the "free speech" amendment to the Constitution. This amendment guarantees every U.S. citizen five freedoms: freedom of religion, speech, press, peaceable assembly, and the freedom to petition the government for redress of grievances. This course examines the historical and philosophical roots of this key constitutional amendment, how it has been fleshed out and defined over time through case law, and the bases of some more recent critics of this amendments and current interpretations.

66-182 Grand Challenges Seminar: Preserving History with Blockchain Technology

Spring: 9 units
Historical information, artifacts, and relics provide a window to our past and help us understand our present and foresee and prepare for the future. During times of conflict and internecine warfare, it is essential to preserve objects of historical and cultural heritage. Blockchain is a block of data chained together. It does three noteworthy things: 1. digitization, 2. tracing, and 3. security. For any non-digital historical data, Blockchain can provide digitization. For any data that requires tracing, such as scientific findings, religious information, or scriptures (including Hadith/sayings of the Prophet (s)), so on, tracing can play a pivotal role in going back to the originator and understanding the change on the way, as well as preserving it from any changes (which is part of security). Blockchain also involves a mining process, which includes stakeholders that audit the information of any newly added block of data, making Blockchain auditable, which is significant for history. Using topics from blockchain technology, history, preservation, and science, this course provides students with the grand challenge of understanding how bitcoin and cryptocurrency can assist in providing potential solutions to the problems of authorship, impermanence, managing shared ownership, and stewardship of artifacts taken through war or colonialism. Many institutions and archives are considering and advocating the merits of blockchain-based repositories. In this Grand Challenge course, we want to examine how the seemingly opposed fields of study - history and blockchain technology - can be synergized to create a futuristic museum that captures monuments and artifacts, making them accessible to future generations.

66-195 Documenting Israeli and Palestinian Food Cultures: Teaching and Travel

Spring: 9 units
How does the study of food cultures allow us to approach cultural intersections, conflict, and peacemaking, especially in a region as fraught as Israel and Palestine? This course, cotaught by CMU faculty in the departments of History, Modern Languages, and the Entertainment Technology Center, is designed to provide students with a historical and cultural background about the hybrid nature of Jewish and Palestinian-Arab cultures and the multiple ethnic contributions to food cultures in Israel/ Palestine, as well as with media-tech skills, with the aim of preparing them for travel to Israel and the West Bank during Spring Break 2023. In the weeks leading up to the trip, the professors will introduce students to the history, literature, film, and language(s) of the region, as well as to critical scholarship in food studies. Students will also begin developing and creating their own personal narrative experience in the media of their choice. During the trip, students will participate in documenting local food cultures through film and other media. Upon their return, they will work on the production of a collaborative multi-layered interactive documentary (iDoc) meant to capture their first-hand experiences with local and regional cuisine practices in Israel and the West Bank, and present separate small group final projects based on these experiences. Specific course themes will include: the shared history of Arabs and Jews from the rise of Islam to Al-Andalus (Muslim Spain) and the Ottoman Empire to the modern and contemporary history of the Arab-Israeli conflict; the history of Sephardi, Ashkenazi, and Mizrahi Jewish immigration and contributions to Israeli cuisine; Palestinian identity, culinary traditions and gendered aspects of food practices; the politics of food; and Palestinian and Jewish voices in literary contexts. To apply to be considered for this course, go to https://forms.gle/UbixDaA9xCBhNaoP8

Course Website: https://forms.gle/UbixDaA9xCBhNaoP8 (https://forms.gle/UbixDaA9xCBhNaoP8/)

66-204 Film Festival

Spring
Students will take on the project of planning and managing a film festival that draws a college- and city-wide audience. Students will collaborate on all aspects of the festival: selecting films, generating and distributing marketing materials, designing and scheduling events, arranging facilities and general logistics, coordinating internal and external public relations, organizing fundraisers, rallying the local communities - in short, all the aspects involved in making the event a spectacular/sensational success! A unique feature of this course-cum-festival will be several directors' participation as guest speakers on the festival theme and other issues informing their films. Previous Film Festivals have covered such topics as: Democracy, Mechanization, Realism, Globalization, Migration, Media and Work. This course is also designed to supplement the study of film with the historical, political and sociological background that students need for critically analyzing the images and ideologies they see on the screen and understand how those images effect our views of the past and present time. NOTE: Interview with course instructor required prior the registration.

66-215 The Innovation Trials

Fall: 9 units
This course will examine some of the most influential intellectual property court battles throughout history and their impact on innovation. This course is geared toward students curious about Americas industrial development and interested in the political and business strategies behind the greatest innovations and technological advances of the past several centuries. The course will answer the who, what, where, when, why and how of a number of legal cases involving various technologies and areas of innovation and place them in their historical context.

66-216 Connecting with the Pittsburgh Community

Spring: 1 unit
This course is designed to engage students in an exploration of various communities within the Pittsburgh area. Students will examine the ways that local organizers have been able to effectively promote positive social change. Students will develop the ability to honor the histories of diverse communities in the region while learning about the communities and the ingredients of successful communities. This course is part of the Dietrich College Community Engagement Fellowship and is only open to students who have been accepted into the program.
Prerequisite: 66-148

66-221 Topics of Law: Introduction to Intellectual Property Law

Intermittent: 9 units
This course provides students with an overview of patent, trademark, copyright, and trade secret laws. Goals for the course include identifying intellectual property (IP) rights and understanding how to take the necessary steps to protect and enforce those rights. Many recent developments in IP law will also be covered.

66-225 Politics, Persuasion, and the Press

Intermittent: 6 units
This course, conducted in the wake of a brutal presidential election, an assault on the Capitol, and a second impeachment, is intended to examine American politics and to look at how the political system in the United States and its interchange with the press shape the process of making policy. It is one part history, one part political science, one part policy studies, with special emphasis on local and national politics. In this course, students will be exposed to the 18th century Constitutional origins of the American political system as well as the 21st century implications of the American political systemall in the context of political upheaval in a country that, until recently, cultivated an air of stability. Through challenging readings, guest speakers, and yeasty class conversation, this course is intended to provide insights into the political system of the preeminent power in North America and, even now, around the world. In addition to the course readings alluded to below, students will be expected each day to have read in detail the Post-Gazette and either The Wall Street Journal or The New York Times, plus websites of your choice. (Rationale: Even in the Internet age, it remains the case that, in the United States, when one person involved in politics and government encounters another by 9 AM, each will have assumed of the other that they have read both The Journal and The Times.)

66-236 Introduction to Environmental Ideas

Fall and Spring: 9 units
By recognizing that environmental problems are themselves complex and require insights from social, political, and scientific perspectives, the interdisciplinary Program in Environmental and Sustainability Studies (ESS) prepares students to gain proficiency in different disciplinary habits of thinking. As part of this endeavor, students take part in informed discussions about interpretive lenses; ways of seeing; and thinking about social, cultural, and historical contexts for interpretations of environment and sustainability. This seminar-style course introduces key methods and approaches for interdisciplinary inquiry within a framework of Environmental Humanities and Environmental Justice. Scholar Giovanna de Chiro writes: "The term 'environmental justice' emerged from the activism of communities of color in the United States in the latter half of the twentieth century...They advocate for social policies that uphold the right to meaningful, democratic participation of frontline communities in environmental decision making." The implications of disciplinary narratives and approaches to questions of environment and sustainability, and the implications for social justice, are a key and repeated question in the course. The role of poverty as a cultural, political, and historical phenomenon is a motif in many of our discussions. We'll explore contrasting historical, cultural, and disciplinary explanations for hunger, famine, and food insecurity. Further, we'll explore how so-called "environmental" explanations for food scarcity, which rationalize the persistence of hunger and poverty in the 21st century, have distracted from decades of expertise, reminding us that hunger and poverty are social problems. In contrast to these so-called "environmental" explanations, there is no scarcity of food in the present era. This course will examine how these narratives contradict each other, and why it matters.

66-300 Using Collective Leadership to Pursue Community Goals

Fall: 6 units
This course serves as the third required course in the Dietrich College Community Engagement Fellowship. This course is designed to further prepare students to actively and thoughtfully engage alongside a community focusing on a topic of the students choice. This course will bring together prior topics of cultural humility, asset-based framing, cultural competence, and community-based leadership models alongside additional topics (such as collective leadership, tailored community-focused communication, among others) responsive to their community-based learning experiences. This will prepare students to narrow their focus on a topic and community in preparation for their capstone project.
Prerequisites: 66-148 and 66-216

66-307 Independent Study

All Semesters
This course is intended for students with a special interest in an interdisciplinary area in the humanities and/or social sciences not covered by a normal course. Readings and other works are developed by the student and an individual faculty member. The number of units will be assigned at the time of registration based on the number of hours to be completed (decided in advance with the sponsoring faculty member).

66-310 Internship

All Semesters: 10 units
Internships-for-credit allow students to apply course-based knowledge in a non-classroom setting, under joint supervision and evaluation by an on-site supervisor and a faculty sponsor. Approved internships must conform to college guidelines for internships-for-credit, and are available by permission only arranged through the Associate Dean's Office in Baker Hall 154.

66-320 Dietrich College Experiential Learning

All Semesters
Experiential Learning occurs when a student participates in an opportunity that allows them to apply what they are learning in the classroom to a real-world context. This may include internships, undergraduate research with a faculty member, community engaged learning, study abroad or work-based learning through structured consulting projects. Students enrolled in this course will be expected to identify several learning goals for their experience, identify a mentor and complete a reflection upon completion. Registration is by permission-only; contact the Director of Experiential Learning.

66-400 Dietrich College Senior Honors Colloquium

Fall: 1 unit
The purpose of this course is to provide students admitted to the Dietrich College Senior Honors Program with a shared set of intellectual and practical sessions that will enhance their senior honors thesis experience. The course will consist of seven bi-weekly 80-minute meetings. Each will be organized around a theme and related topics that are relevant to the senior honors thesis experience, and that take advantage of both the high caliber and interdisciplinary diversity of the course members. Guest visitors will also be a common feature of the course. Topics could include: the meaning(s) of "honors;" getting started and keeping pace: the ebb and flow of an independent research project (including how to recognize and avoid procrastination; forging a successful relationship with your thesis advisor - the myth of the separation of research from writing; writing for publication); ethics in research; "interdisciplinarity," or the "unity of knowledge;" funding for research; preparing for and delivering effective presentations; intellectual property rights, and human subjects policy. Guest speakers invited to address and engage class members in discussion/debate of topics that lend themselves to interdisciplinary discussion and debate (e.g., stem cell research, which calls into play science, ethics, etc.). Course requirements will include mandatory attendance, occasional readings (where appropriate), acting as co-leader for at least one session, and - at course's end - (a) a written, formal preliminary thesis statement and action plan, endorsed by the thesis advisor, and tentatively, (b) a brief oral presentation of the thesis statement and plan to the class + thesis advisors during the last class meeting. All students will participate in critiques of fellow-students' presentations and plans.

66-402 Dietrich Leadership Development Seminar

Fall and Spring: 9 units
The Dietrich Leadership Development Seminar is for juniors and seniors in Dietrich College wishing to advance their understanding of leadership theory and practice and to develop their own skills in this regard, while creating a context for their lifelong leadership development. The course is predicated on a six pillar model proposing that ideal leaders must at once be visionary, ethical, engaging, tactical, technical - including sub-expert conversancy in realms beyond their own expertise, and reflective - including both personal mindfulness and assessment against clear metrics. In this context, the course includes a focus on strategic planning, teamwork, cultural awareness, conflict resolution, risk management, sustainability and personal welfare, professionalism, personal financial planning, and ongoing professional development. The course includes an attendance requirement and active engagement in class discussion, assigned readings/videos/podcasts (2 hours/week), self-selected experiential opportunities (2 hours/week), reflective journaling (2 hours/week), three hour-long one:ones per semester with the instructor, special guests who are leaders in various occupational and service domains, a mid-term, a final, and a final presentation. The course includes case studies and role plays to amplify the learning experience. The course is limited to twelve students, with registration based on approval of the faculty member.

66-403 Community Engagement Fellowship Capstone

Spring
This course serves as the final component of the Dietrich College Community Engagement Fellowship and is designed to engage students in completion of their culminating project. The course will build on students' work in the previous semester in which they identified a community, established an understanding of the community goals and proposed a plan to pursue one of these goals. During the semester, students will implement their capstone project utilizing the knowledge and skills developed during earlier stages of the program. Working with a mentor who is also a community stakeholder, students will implement their project, solicit feedback from the community, evaluate project effectiveness and make appropriate changes. Students will also articulate ways their project can be sustained and present their findings to a variety of audiences.
Prerequisites: 66-148 and 66-216 and 66-300

66-501 Dietrich College Senior Honors Thesis I

Fall and Spring: 9 units
This is the first semester of a two-semester sequence that culminates in an original, year-long independent research or creative project. The course is open only to students who have been approved for entry into the Dietrich College Senior Honors Program. Thesis topics are selected by faculty and students, and reviewed and approved through the senior honors program application process. Dietrich College senior honors students are also required to participate in the annual Meeting of the Minds Undergraduate Research Symposium, offering either an oral presentation or poster session based on their senior honors thesis

Course Website: http://www.cmu.edu/dietrich/undergraduate/programs/shp/index.html (http://www.cmu.edu/dietrich/undergraduate/programs/shp/)

66-502 Dietrich College Senior Honors Thesis II

Fall and Spring: 9 units
This is the second semester of a two-semester sequence that is the culmination of an original, year-long independent research or creative project. The course is open only to students who have been approved for entry into the Dietrich College Senior Honors Program. Thesis topics are selected by faculty and students, and reviewed and approved through the senior honors program application process. Dietrich College senior honors students are also required to participate in the annual Meeting of the Minds Undergraduate Research Symposium, offering either an oral presentation or poster session based on their senior honors thesis
Prerequisite: 66-501

Course Website: http://www.cmu.edu/dietrich/undergraduate/programs/shp/index.html (http://www.cmu.edu/dietrich/undergraduate/programs/shp/)

66-503 Dietrich College Senior Honors Thesis

All Semesters: 18 units
This course is a one-semester alternative to the two-semester Dietrich College Senior Honors Thesis sequence 66-501/66-502. The course is open only to students who have been approved for entry into the Dietrich College Senior Honors Program, and whose senior honors thesis project has been approved as a one-semester undertaking. Thesis topics are selected by faculty and students, and reviewed and approved through the senior honors program application process. The thesis culminates in an original independent research or creative project. Dietrich College senior honors students are also required to participate in the annual Meeting of the Minds Undergraduate Research Symposium, offering either an oral presentation or poster session based on their senior honors thesis.

66-504 Senior Capstone I

All Semesters: 9 units
Dietrich College student-defined majors (primary or additional) must complete a senior capstone project for at least 9 units (in one semester), or 18 units across both semesters of the senior year. The capstone project culminates in an original independent research or creative project that draws on all of the strands of the student's particular student-defined program. This course is the first in a two-course capstone sequence open only to seniors who have been admitted to the Dietrich College Student-Defined Program as a primary or additional major, and who choose the two-semester capstone sequence option. The second course in the sequence is 66-505, Senior Capstone II. Projects are proposed by eligible students, and must be approved by a member of the faculty who agrees to be the project's primary advisor, as well as by the Dietrich College Student-Defined Program Director. These approvals must be secured no later than registration week of the semester prior to the start of the student's senior year. NOTE: For Dietrich College student-defined majors (primary or additional) who are accepted into the Dietrich College Senior Honors Program and who successfully complete a senior honors thesis based primarily on their student-defined major, the senior honors thesis fulfills the student-defined major capstone requirement.

66-505 Senior Capstone II

All Semesters: 9 units
Dietrich College student-defined majors (primary or additional) must complete a senior capstone project for at least 9 units (in one semester), or 18 units across both semesters of the senior year. The capstone project culminates in an original independent research or creative project that draws on all of the strands of the student's particular student-defined program. This course is the second in the two-course capstone sequence, and is open only to seniors who have been admitted to the Dietrich College Student-Defined Program as a primary or additional major, and who have chosen the two-semester capstone option. The first course in the sequence is 66-504, Senior Capstone I. Projects are proposed by eligible students, and must be approved by a member of the faculty who agrees to be the project's primary advisor, as well as by the Dietrich College Student-Defined Program Director. These approvals must be secured no later than registration week of the semester prior to the start of the student's senior year. NOTE: For Dietrich College student-defined majors (primary or additional) who are accepted into the Dietrich College Senior Honors Program and who successfully complete a senior honors thesis based primarily on their student-defined major, the senior honors thesis fulfills the student-defined major capstone requirement.

66-506 Senior Capstone

All Semesters: 9 units
Dietrich College student-defined majors (primary or additional) must complete a senior capstone project for at least 9 units (in one semester), or 18 units usually spread across both semesters of the senior year. The capstone project culminates in an original independent research or creative project that draws on all of the strands of the student's particular student-defined program. This course is a one-semester option for student-defined majors who propose a 9-unit/one-semester capstone project; it is also an 18-unit/one-semester alternative to the two-semester Senior Capstone sequence (66-504/66-505) for Dietrich College student-defined majors who choose the 18-unit capstone option, but who are unable to spread these units across both semesters of the senior year. The course is open only to seniors who have been admitted to the Dietrich College Student-Defined Program as either a primary or additional major. Projects and unit values are proposed by eligible students, and must be approved by a member of the faculty who agrees to be the project's primary advisor, as well as by the Dietrich College Student-Defined Program Director. These approvals must be secured no later than registration week of the semester prior to the start of the student's senior year. NOTE: For Dietrich College student-defined majors (primary or additional) who are accepted into the Dietrich College Senior Honors Program and who successfully complete a senior honors thesis, the senior honors thesis fulfills the student-defined major capstone requirement.

General Dietrich College Courses

65-198 Research Training: History

Intermittent: 9 units
For Fall 2021: The Pittsburgh Queer History Project The Pittsburgh Queer History Project (PQHP) is an ongoing research effort to collect and catalog archival material that document the experiences of LGBTQ people in Pittsburgh and its environs from the second half of the 20th century to the present. The PQHP is co-directed by Prof. Tim Haggerty, the Director of the Humanities Scholars Program and Dr. Harrison Apple, a BXA graduate of Carnegie Mellon who received a doctorate degree from the University of Arizona in 2021, studying with the noted trans scholar Susan Stryker. Students will meet with community activists, learn how to conduct community outreach, organize archival material, and help formulate research questions based on these documents. There is no prior experience needed. The Dietrich College research training program is open to second-semester first-year students and sophomores with a 3.0 QPA or by petition. By permission of the relevant professor and the Director of Undergraduate Studies. Students sign up for these courses through both the History Department and the Dietrich College Dean's Office.

65-200 Applied Quantitative Social Science I

Fall: 9 units
The first course in the QSSS core sequence provides a fast-paced introduction to a range of methods in the quantitative social sciences. Organized around a set of case studies, the course introduces the language and methods of empirical research through a combination of seminar-style discussions of academic papers, and hands-on lab work using the statistical software R. Students will replicate results from a high-profile labor market discrimination paper, explore agent-based models of neighborhood segregation, and scrape Wikipedia data to examine imbalances in gender representation. Enrollment restricted to QSSS students.

65-201 Humanities Scholars III

Fall: 9 units
Fall 2021: Modern Love As an emotional state love is central to the human experience, whether it is the bonding that occurs between parents and their children, the camaradierie that happens between friends, colleagues, or compatriots, or the romantic attachments that occur between partners. In the modern era, love underwent a transformation: children became more precious, comradeship was reexamined and romance assumed a preeminent place in psychology, legal theory, and social organization. None of this was immutable or unchanging. This class, utilizing fiction, social science and other media, will examine the manner in which love has transformed over time and the consequences that these changes have had upon our understanding of personal interactions, sexualities, and conceptions of health, wellness and social order.
Prerequisite: 65-102

Course Website: http://www.hss.cmu.edu/hsp/

65-203 Applied Quantitative Social Science II

Spring: 9 units
Applied Quantitative Social Science II is the second course in the QSSS core sequence. Conducted in a seminar format, the course will feature guest lectures from a series of faculty at CMU. Students will discuss ongoing research across the social sciences, and over the course of the semester will develop a research project proposal. Seminar participation is limited to QSSS students.

Heinz College of Information Systems and Public Policy

Ramayya Krishnan, Dean
Location: 1003 Hamburg Hall
www.heinz.cmu.edu (http://www.heinz.cmu.edu)

The next generation of leaders must deeply understand this critical point of intersection: People, policy, and technology. The connections between the three define our time, and will continue to shape the future of humankind.

At Heinz College, we've understood this since our founding, and we provide students with a foundation of data analytics, technology, evidence-based management, and rich experiential learning in contexts that are crucial to society, such as public policy, health care, information systems, cybersecurity, the arts, and entertainment.

Our research programs are best described as data-intensive social science. Our economists, statisticians, operations researchers, computer scientists, and management experts sit side by side, collaborating constantly and not sitting in traditional departmental silos. For this reason, they are able to approach complex societal problems in an altogether different way and impart this interdisciplinary mindset to our students.

The unique co-location of our two schools, the School of Public Policy and Management (https://www.heinz.cmu.edu/about/public-policy-management/) and the School of Information Systems and Management (https://www.heinz.cmu.edu/about/information-systems-management/), offers opportunities for collaboration that simply cannot be duplicated elsewhere. We also offer two groundbreaking Joint Degree Programs with the CMU College of Fine Arts (https://www.heinz.cmu.edu/about/fine-arts/).

Graduates of Heinz College are highly sought by employers across sectors for their interdisciplinary expertise and ability to use relevant data to solve complex problems. Our alumni work for government agencies at the federal, state, and local levels. They work in roles that directly impact national security. They work for tech giants, big consulting firms, major media outlets, cultural institutions, top hospitals and health systems, non-profits, and community organizations of all sizes. They work for startups—or they found their own.

Learn more about Heinz College graduate degree programs (https://www.heinz.cmu.edu/programs/).

Public Interest Technology

Public Interest Technology (PIT) is an emerging field unto itself, but Carnegie Mellon University has been a leader in this space for over 50 years, promoting the use of technology to advance the public interest. Continued excellence in this space is a priority for Heinz College.

Learn more about PIT at Heinz College (https://www.heinz.cmu.edu/about/public-interest-technology/).

Minor in Decision Analytics and Systems (DAS)

Students in any undergraduate major at Carnegie Mellon University can elect the Minor in Decision Analytics and Systems (DAS), building along the way a robust interdisciplinary toolkit that draws on computer science, economics, statistics, operations research, machine learning, and information systems. You will also learn how-to apply this toolkit to consequential societal problems!

Heinz College offers the undergraduate **Minor in Decision Analytics and Systems (DAS)**, providing you with the opportunity to add systems thinking and evidence-based problem solving to any field of study.

Data is a means to an end—creating value for people and society. But before data can create value, there comes a critical decision point. DAS prepares you to be the one who makes that decision, navigating the process from end to end: from identifying a current decision point and the problem it could solve, to determining the right decision and its potential value, and finally communicating that value and putting the decision into action.

Using Heinz College's deep expertise in analytics, public policy and information systems as a launchpad, the DAS minor features gamechanging experiential courses that ground DAS strategies in real world application, so you can see the social impacts of this work firsthand.

For more information, contact Professor Raja Sooriamurthi at raja@cmu.edu.

DAS MINOR CURRICULUM AND COURSEWORK

DAS Core Courses:

- Introduction to DAS (94-416 Introduction to Decision Analytics and Systems)
- Simulation for DAS (94-417)
- Optimization for DAS (94-433 Optimization for DAS)
- Applied Econometrics for DAS (94-431 Applied Econometrics for DAS)
- Critical Analysis of Policy Research (90-440 Critical Analysis of Policy Research)
- Machine Learning for Public Policy Lab (94-489 Machine Learning for Public Policy Lab)

Expected Pre-requisites:

- Calculus (21-111 Calculus I, 21-112 Calculus II, OR 21-256 Multivariate Analysis)
- Matrix Algebra (21-240 Matrix Algebra with Applications)
- Computer Science (15-112 Fundamentals of Programming and Computer Science AND 15-122 Principles of Imperative Computation)
- Probability and Statistics (36-225 Introduction to Probability Theory AND 36-226 Introduction to Statistical Inference)
- Principles of Microeconomics (73-102 Principles of Microeconomics)

SAMPLE SCHEDULE: DAS

*Below is one possible schedule for the **DAS minor**. Actual schedules may vary based on course availability and other factors.*

Year Two - Fall Semester

- Introduction to DAS
- Optimization for DAS

Year Two - Spring Semester

- Simulation for DAS
- Applied Econometrics for DAS

Year Three - Fall Semester

- Critical Analysis of Policy Research

Year Three - Spring Semester

- Machine Learning for Public Policy Lab

Minor in Health Care Policy and Management

Sponsored by:
Heinz College of Information Systems and Public Policy
Dietrich College of Humanities and Social Sciences
Mellon College of Science

Faculty Advisors:
Jason D'Antonio, Mellon College of Science
James F. Jordan, H. John Heinz III College

The face of health care is changing. The practice of medicine is being fundamentally altered by the forces of change in public policy, health care organizations and in the industry as a whole. The role of individual professionals in this industry is changing as rapidly as the industry itself. Traditional career paths have disappeared overnight to be replaced by new opportunities that require new skills. New organizations are placing new demands on their professional and medical staffs. The criteria of efficiency and financial stability are entering the domains of diagnosis and treatment.

This minor is designed to provide students considering a career in the health professions with an understanding of how these changes are likely to affect their careers. Students will become familiar with the critical policy and management issues and will begin to learn to operate effectively in the emerging health care environment. The curriculum combines economic, organizational, managerial, historical and psychological perspectives on these issues to provide a foundation for a deepened understanding of the changing structure of health care organizations and policy.

Required Courses for HCPM Minor

A total of 54 units are required to complete this minor. Entry into the minor requires completion of 73-102 Principles of Microeconomics or the equivalent by approval.

Required Courses

Complete a total of 21 units from the following:		
79-330	Medicine and Society: Health, Healers, and Hospitals	9
90-436	Health Systems	6
90-472	Health Policy	6

Elective Courses

Complete a minimum of 24 units from these two sections:

Heinz College Courses		
94-409	Healthcare Information Systems	12
73-328	Health Economics	12
90-832	Health Law	6
90-433	Population Health	6
90-834	Health Care Geographical Information Systems	12
Other courses as approved		

Humanities and Social Sciences Courses (9 units each)		
80-245	Medical Ethics	9
76-494	Healthcare Communications	9
88-365	Behavioral Economics and Public Policy	9
42-444	Medical Devices	9
Other courses as approved		

Please note that some of these courses have prerequisites that will not count toward the completion of the requirements for this minor.

Elective Focus Areas

Focus areas are suggested groupings of electives based on student interest. Students *do not* need to take all electives within one focus area; they are free to choose their 18-unit elective minimum from any combination of focus areas.

Health Management/Administration Focus		Units
90-832	Health Law	6
80-245	Medical Ethics	9
76-494	Healthcare Communications	9

Health Policy Focus		Units
73-328	Health Economics	12
90-832	Health Law	6
90-433	Population Health	6
88-365/90-882	Behavioral Economics and Public Policy	9
Other courses as approved		

Health Analytics & IT Focus		Units
94-409	Healthcare Information Systems	12
90-834	Health Care Geographical Information Systems	12
42-444	Medical Devices	9
Other courses as approved		

Five-Year (Accelerated) Master's Programs

Students with the drive to develop as leaders and enter the job market more quickly can earn their CMU undergraduate degree **and** a professional master's degree from Heinz College together in five years instead of the typical six.

An Accelerated Master's Program (AMP) isn't just a savings of time. It's also a considerable savings in cost, and adds a tremendous level of experience and expertise in a specific industry.

In the Heinz College AMP program, students complete 3 years in a CMU undergraduate program (any major), followed by 1 year of integrated study, followed by 1 full year at Heinz College.

The following Heinz College master's degree programs offer accelerated options for CMU undergraduates:

- Master of Arts Management (MAM)
- Master of Entertainment Industry (MEIM)*
- Master of Information Systems Management (MISM)
- Master of Science in Health Care Policy and Management (MSHCPM)
- Master of Science in Information Security Policy and Management (MSISPM)
- Master of Information Security Policy and Management (MSISPM)
- Master of Science in Public Policy and Management (MSPPM)*

Students must apply and be admitted to Heinz College. Learn more about Heinz College admissions requirements (https://www.heinz.cmu.edu/admissions/).

For more information on Accelerated Master's Programs, please contact the Heinz College Office of Admissions at hnzadmit@andrew.cmu.edu or by phone 412-268-2164.

***Note on AMP planning for MEIM and MSPPM - Washington, D.C.:** Due to the rigorous format and unique academic demands of the MEIM and MSPPM – Washington D.C. programs—with their second years at CMU's Los Angeles and D.C. campuses, respectively—interested students should begin the AMP planning process as early as possible in their undergraduate career. Students must ensure that they have satisfied all requirements for their undergraduate degree, as well as their first-year master's requirements, by the end of the fourth AMP year.

Ph.D. Program

Distinguished by the interdisciplinary model of Heinz College and Carnegie Mellon University, our Ph.D. programs prepare graduates to lead change in their chosen fields through meaningful collaborations and hands-on work with our renowned and extremely accessible faculty.

Heinz College features the unique co-location of two schools: The School of Information Systems and Management and The School of Public Policy and Management; however, below that larger structure, we are a college without departments and their characteristic silos. Our faculty, students, and research centers thrive by working together to solve problems across subjects, disciplines, and business verticals.

In the Heinz College Ph.D. program, you will conduct innovative research to address increasingly complex challenges facing society, whether those challenges are technical, organizational, political, economic, social, or—as is often the case—some combination thereof.

- Ph.D. in Information Systems and Management (https://www.heinz.cmu.edu/programs/phd-programs/information-systems-management/)
- Ph.D. in Public Policy and Management (https://www.heinz.cmu.edu/programs/phd-programs/public-policy-management/)
- Joint Ph.D. Programs (https://www.heinz.cmu.edu/programs/phd-programs/joint-phd/)
- Recent Ph.D. Placements (https://www.heinz.cmu.edu/programs/phd-programs/phd-placements/)

Contact:
Michelle Wirtz, Ph.D. Program Manager
4800 Forbes Avenue
Hamburg Hall 3014
Pittsburgh, PA 15213
412-268-4418
mwirtz@andrew.cmu.edu

Faculty and Research Centers

FACULTY

Heinz College has an international reputation for the quality of its research. Our interdisciplinary environment creates exciting opportunities for collaboration and produces a breadth of research work not typically found in schools of our size.

Our faculty and research centers consistently receive funding support from government agencies, foundations and corporate partners, like the National Science Foundation; the Heinz Endowments; the Mellon Foundation; the

U.S. Departments of Defense, Commerce, Health and Human Services, and Housing and Urban Development; the Sloan Foundation; and the National Institute of Justice.

Visit our Faculty pages (https://www.heinz.cmu.edu/faculty-research/) to learn more about individual faculty members, accomplishments, and current research.

RESEARCH CENTERS

We host, or are closely associated with, these CMU research centers:

- Arts Management and Technology Laboratory (AMTLab) (http://amt-lab.org/)
- Block Center for Technology and Society (https://www.cmu.edu/block-center/)
- Center for Behavioral Decision Research (CBDR) (http://cbdr.cmu.edu/)
- Center for Economic Development (CED) (https://www.heinz.cmu.edu/ced/)
- CyLab (http://www.cylab.cmu.edu/)
- Digital Transformation and Innovation Center (https://www.cmu.edu/risk-reg-center/)
- iLab (http://ilab.heinz.cmu.edu/)
- Initiative for Digital Entertainment Analytics (IDEA) (http://idea.heinz.cmu.edu/)
- Living Analytics Research Centre (LARC) (https://larc.smu.edu.sg/)
- Metro21: Smart Cities Institute (https://www.cmu.edu/metro21/)
- Mobility21: USDOT National University Transportation Center (https://mobility21.cmu.edu/)
- Privacy Economics Experiments (PEEX) Lab (https://peex.heinz.cmu.edu/)
- Program for Research and Outreach on Gender Equity in Society (PROGRESS) (https://www.cmu.edu/dietrich/progress-equity-leadership/)
- Traffic21 (https://traffic21.heinz.cmu.edu/)

Diversity and Inclusion

The Heinz College of Information Systems and Public Policy represents over 50 nations and over 40 U.S. states, which increases our ability to foster a community with greater variation in perspectives and approaches to our work.

By design, Heinz College is an empathetic and open environment that inspires continuous learning, conversation, and intelligent action that will impact society for the better.

Diversity, inclusion, and equity are not radical concepts. Rather, the ongoing pursuit of these ideals is fundamental to the energetic exchange of ideas; the success of our students, faculty, and staff; and the unlocking of innovations that will improve the human condition.

Heinz College proudly champions the unique experiences of all members of our campus community. It is a priority for Heinz College to attract, maintain, and nurture a student body of diverse viewpoints, backgrounds, and talents. We are also committed to improving access to our graduate programs, in particular for underrepresented populations. We support these efforts through a variety of initiatives, programming, and partnerships in addition to Carnegie Mellon University's campus-wide efforts.

Learn more about Diversity & Inclusion at Heinz College (https://www.heinz.cmu.edu/about/diversity/).

CONTACT

Director of Admissions
Heinz College of Information Systems and Public Policy
Carnegie Mellon University
Pittsburgh, PA 15213

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www.heinz.cmu.edu (http://www.heinz.cmu.edu)

Faculty

ALESSANDRO ACQUISTI, Assistant Professor of Information Systems and Public Policy – Ph.D., UC Berkeley; Carnegie Mellon, 2003–

LEMAN AKOGLU, Dean's Associate Professor of Information Systems – PhD, Computer Science, Carnegie Mellon University; Carnegie Mellon, 2012–

UTTARA ANANTHAKRISHNAN, Assistant Professor of Information Systems – Ph.D. in Information Systems, Heinz College at Carnegie Mellon University;

LINDA BABCOCK, James M. Walton Professor of Economics – Ph.D., University of Wisconsin at Madison; Carnegie Mellon, 1988–

EDWARD BARR, Associate Teaching Professor – M.S., Indiana University of Pennsylvania; Carnegie Mellon, 2000–

MARTIN BARRETT, Associate Teaching Professor – Ph.D. in Commputer Science, University of Wisconsin-Madison;

DAREEN BASMA, Assistant Dean of Diversity, Inclusion, Climate & Equity (DICE) – Bachelor's degree in Psychology & Religious Studies, Master's degree in Mental Health Counseling, Ph.D. in Counselor Education & Supervision, University of Tennessee;

ELI BEN-MICHAEL, Assistant Professor – PhD in Statistics, U.C. Berkeley;

ALFRED BLUMSTEIN, J. Erik Jonsson University Professor of Urban Systems and Operations Research; Director, National Consortium on Violence Research – Ph.D., Cornell University; Carnegie Mellon, 1969–

SILVIA BORZUTSKY, Associate Teaching Professor – Ph.D., University of Pittsburgh; Carnegie Mellon, 2001–

LEE BRANSTETTER, Associate Professor of Economics – Ph.D., Harvard University; Carnegie Mellon, 2006–

JONATHAN CAULKINS, Professor of Operations Research and Public Policy; Faculty Chair, Master of Public Policy and Management Program – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1990–

GEORGE CHEN, Assistant Professor of Information Systems – Ph.D. in Electrical Engineering and Computer Scienc, MIT; Carnegie Mellon, 2015–

DAVID CHOI, Assistant Professor of Statistics and Information Systems – Ph.D, Electrical Engineering, Stanford University; Carnegie Mellon, 2004–

JACK CHOW, Distinguished Service Professor – M.D., University of California at San Francisco School of Medicine; Carnegie Mellon, 2011–

KAREN CLAY, Assistant Professor of Economics and Public Policy – Ph.D., Stanford University; Carnegie Mellon, 1997–

AVINASH COLLIS, ssistant Professor at the Heinz College of Information Systems and Public Policy – Ph.D. from the Sloan School of Management, Massachusetts Institute of Technology;

BRETT ASHLEY CRAWFORD, Associate Teaching Professor of Arts Management – Ph.D. in Theatre History and Criticism, University of Maryland;

GEORGE T. DUNCAN, Professor of Statistics, Emeritus – Ph.D., University of Minnesota; Carnegie Mellon, 2011–

MARIANA ESCALLON BARRIOS, Assistant Teaching Professor of Information Systems – Ph.D. in Industrial Engineering and Management Sciences, Northwestern University;

PEDRO FERREIRA, Associate Professor of Information Systems – PhD, Engineering and Public Policy Specialization in Telecom Policy, Carnegie Mellon University; Carnegie Mellon, 2004–

REBEKAH FITZSIMMONS, Assistant Teaching Professor of Professional Communication – PhD in English, University of Florida;

ANDREW GARIN, Assistant Professor of Economics – Ph.D., Harvard University;

MARTIN GAYNOR, E.J. Barone Professor of Economics and Health Policy; Faculty Chair, Ph.D. Program – Ph.D., Northwestern University; Carnegie Mellon, 1995–

RAYID GHANI, Distinguished Career Professor – Machine Learning, Carnegie Mellon University;

WILLIAM GOGOLAK, Assistant Teaching Professor – PhD in Finance, Illinois Institute of Technology;

GABRIELA GONGORA-SVARTZMAN, Assistant Teaching Professor of Information Systems – PhD in Engineering Management, Stevens Institute of Technology, School of Systems and Enterprises;

CHRISTOPHER GORANSON, Distinguished Service Professor – Master of Geographic Information Systems, Penn State University;

WILPEN GORR, Professor of Public Policy and Information Systems – PhD, Operations Research, Carnegie Mellon University;

COREY HARPER, Assistant Professor of Civil and Environmental Engineering – BS in Civil Engineering, MS and PhD , Morgan State University, Carnegie Mellon University;

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AKSHAYA JHA, Assistant Professor of Economics and Public Policy – Ph.D. in Economics, Stanford University;

MARK S. KAMLET, Provost, CMU, and H. John Heinz III Professor of Economics and Public Policy – Ph.D., University of California at Berkeley; Carnegie Mellon, 1978–

FELIX KOENIG, Assistant Professor of Economics – Ph.D. and MSc in Economics, London School of Economics;

BRIAN KOVAK, Associate Professor of Economics and Public Policy – Ph.D., Economics, University of Michigan;

DAVID KRACKHARDT, Professor of Organizations and Public Policy – Ph.D., University of California at Irvine; Carnegie Mellon, 1991–

RAMAYYA KRISHNAN, William W. and Ruth F. Cooper Professor of Management Science and Information Systems; Faculty Chair, Master of Information Systems Management Program – Ph.D., University of Texas at Austin; Carnegie Mellon, 1987–

KRISTIN KURLAND, Associate Teaching Professor (joint with School of Architecture) – B.A., University of Pittsburgh; Carnegie Mellon, 1999–

CHRIS LABASH, Assistant Teaching Professor

DAVID LASSMAN, Distinguished Service Professor of Organizational Management – BS, Mechanical and Aerospace Engineering, MBA, Princeton University, Harvard Business School;

GORDON LEWIS, Associate Professor of Sociology; Faculty Chair, Master of Public Management Program – Ph.D., Stanford University; Carnegie Mellon, 1969–

BEIBEI LI, Associate Professor of IT and Management – PhD in Information Systems, Stern School of Business, New York University;

ARI LIGHTMAN, Practice Professor, Digital Media and Marketing – M.B.A., Carnegie Mellon University; Carnegie Mellon, 2011–

PETER MADSEN, Senior Lecturer in Ethics and Public Policy – Ph.D., Duquesne University; Carnegie Mellon, 1988–

DAN MARTIN, Director, Master of Arts Management Program, and Associate Professor (College of Fine Arts) – M.F.A., Brooklyn College/City University of New York; Carnegie Mellon, 1993–

HAYLEE MASSARO, Assistant Teaching Professor

ANNA MAYO, Assistant Professor of Organizational Behavior – PhD in Organizational Behavior & Theory, Carnegie Mellon's Tepper School of Business;

MICHAEL MCCARTHY, Associate Teaching Professor of Information Systems Management – M.S., University of Pittsburgh; Carnegie Mellon, 1999–

SARAH MENDELSON, Distinguished Service Professor of Public Policy and Head of Heinz College in Washington, DC – PhD in Political Science, Columbia University;

JOE MERTZ, Associate Teaching Professor – Ph.D., Carnegie Mellon; Carnegie Mellon, 1994–

DANIEL NAGIN, Theresa and H. John Heinz III Professor of Public Policy, and Research Director, National Consortium on Violence Research – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1979–

JOHN OSTLUND, Clinical Professor of Information Systems

REMA PADMAN, Professor of Operations Research and Information Management; Faculty Chair, Master of Science in Health Care Policy and Management Program – Ph.D., University of Texas at Austin; Carnegie Mellon, 1989–

SEAN QIAN, Henry Posner, Anne Molloy, and Robert and Christine Pietrandrea Associate Professor of Civil Engineering; Director, Mobility Data Analytics Center (MAC) – PhD, University of California Davis;

SETH RICHARDS-SHUBIK, Assistant Professor of Economics and Public Policy – Ph.D., University of Pennsylvania; Carnegie Mellon, 2011–

DAVID RIEL, Distinguished Service Professor – Ph.D. ABD in Education, West Virginia University;

STACY ROSENBERG, Associate Teaching Professor – MA in Media, Culture, and Communication, New York University;

DENISE ROUSSEAU, H. J. Heinz II Professor of Organizational Behavior (joint with Graduate School of Industrial Administration) – Ph.D., University of California at Berkeley; Carnegie Mellon, 1994–

ANANYA SEN, Assistant Professor of Information Technology and Management – Ph.D in Economics, Toulouse School of Economics;

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MICHAEL SMITH, Assistant Professor of Information Technology – Ph.D., Alfred P. Sloan School of the Massachusetts Institute of Technology; Carnegie Mellon, 2000–

RAJA SOORIAMURTHI, Teaching Professor Information Systems Program, Director Decision Analytics and Systems minor

DAVID STEIER, Distinguished Service Professor – Doctor of Philosophy (PhD) in Computer Science, Carnegie Mellon University;

JILLIAN STEPHENSON, Assistant Teaching Professor; Certified Public Accountant – Bachelor of Science in Business Administration, Accounting, University of Pittsburgh;

ROBERT STRAUSS, Professor of Economics and Public Policy; Faculty Chair, Master of Science in Educational Technology Management Program – Ph.D., University of Wisconsin; Carnegie Mellon, 1979–

LAURA SYNNOTT, Associate Teaching Professor, Healthcare Policy and Management – M.S., Health Services Administration, University of Michigan; Carnegie Mellon, 2004–

JANUSZ SZCZYPULA, Associate Teaching Professor in Information Systems – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2000–

JOEL TARR, Richard S. Caliguiri Professor of Urban and Environmental History and Policy – Ph.D., Northwestern University; Carnegie Mellon, 1967–

LOWELL TAYLOR, Professor of Economics and Public Policy; Associate Dean of Faculty – Ph.D., University of Michigan; Carnegie Mellon, 1990–

RAHUL TELANG, Assistant Professor of Information Systems – Ph.D., Carnegie Mellon; Carnegie Mellon, 2001–

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HOLLY WIBERG, Assistant Professor of Operations Research and Public Policy – PhD in Operations Research, MIT;

PETER ZHANG, Assistant Professor of Operations Research – Ph.D. in Engineering Systems, Massachusetts Institute of Technology;

SHIXIANG ZHU, Assistant Professor of Data Analytics – Ph.D. in Machine Learning, Georgia Institute of Technology; Carnegie Mellon, 2022–

Mellon College of Science

Curtis Meyer, Interim Dean

Maggie Braun, Associate Dean for Undergraduate Affairs

Kenneth Hovis, Assistant Dean for Educational Initiatives

Location: Doherty Hall 1324
www.cmu.edu/mcs (http://www.cmu.edu/mcs/)

The Mellon College of Science (MCS) has provided the undergraduate training for many of today's leading scientists. We have earned national recognition for our integration of undergraduate education and research from such organizations as the National Science Foundation, the Howard Hughes Medical Institute, and the Beckman Foundation. MCS students gain a broad education in science, mathematics, and the liberal arts while using state-of-the-art computational approaches in their courses, laboratories, and research activities. Our faculty members are committed to teaching as well as to a wide range of scientific research. This combined emphasis on education and research brings special benefits to students, including increased awareness of current scientific developments that are incorporated in classroom instruction, and, most importantly, opportunities to participate with faculty, graduate students, and other research scientists in a variety of research projects.

In the context of rigorous training in each field, the MCS curriculum emphasizes problem-solving, communication, and analytical skills, and it teaches our students the value of hard work and discipline. Our students go on to highly successful careers in a broad range of fields like astrophysics, biotechnology, computer science, business management, environmental science, health care policy, investment banking, marketing analysis, medicine, patent law, and pharmaceuticals. Our alumni credit their education in science for preparing them for a lifetime of learning and achievement; their employers attest to their ability to succeed and to continue learning in an ever-changing world.

The MCS Departments of Biological Sciences, Chemistry, Mathematical Sciences, and Physics each outline their degree programs and courses in the departmental sections. Students select their major in the spring of the first year so that the sophomore year begins with a focus within a department. Most of the courses required within a major are scheduled in the sophomore and junior years, leaving much of the senior year and part of the junior year open for electives. This provides the opportunity to participate in undergraduate research, explore interdisciplinary studies, study abroad, pursue additional majors or minors in other fields, or take other specialty courses oriented toward immediate job placement upon graduation or entry into graduate studies.

Science education in the 21st Century demands educational experiences that are much broader than the traditional preparation of a scholar in a chosen field of science. We want our MCS graduates to be **scholars** who are deeply trained in their discipline(s), and also **professionals** adept at communicating to broad audiences, accustomed to working in diverse, multidisciplinary teams, and keenly aware of the global context of their work. We want them to be **citizens** who are actively involved and globally engaged, and to grow as **persons** with a sense of wellness and balance.

With these ambitions in mind, we have set forth fifteen (15) outcomes that all MCS undergraduate students should complete in their time at Carnegie Mellon. Upon graduation, MCS students should be able to:

1. Apply foundational and advanced mathematical and scientific knowledge in a chosen field of study appropriately and fluently to solve complex problems, to integrate concepts across disciplines, and to adapt their knowledge to new situations.
2. Critically assess their current state of knowledge and expertise and acquire new knowledge in pursuit of both specific scientific goals and new intellectual interests broadly throughout their lifetime.
3. Communicate effectively via oral, visual, and written formats with an understanding of the perspectives and expectations of diverse audiences, including those within their chosen discipline, outside that discipline (but within STEM), and non-scientists.
4. Participate effectively in multidisciplinary research and/or other teams pursuing a shared vision while optimizing team outcomes.
5. Use the appropriate tools and required media literacy to acquire, assess, and analyze data and information from diverse sources.
6. Recognize and explain the importance of at least one current research topic in a STEM field outside of their major.
7. Recognize and explain the similarities and differences in analyzing/approaching problems, including in technical and non-technical fields other than their major.
8. Demonstrate knowledge of the arts, humanities, and social sciences.
9. Recognize the interplay of science, society, public policy, business, and economics.
10. Identify global examples of the reciprocal relationships among science, technology, political forces, societal contexts, and environmental issues.
11. Describe multiple similarities and differences between one's own culture and that of others.
12. Engage in recursive, reflective processes to assess their own levels of physical, emotional, and social wellness and then to choose activities that promote these aspects of wellness.
13. Engage in recursive, reflective processes to balance multiple endeavors by setting priorities and managing time in academic, meta-curricular, and personal dimensions.
14. Recognize ethical issues and appreciate the complexities of interrelationships among them, and the use of information in ethical and legal manners.
15. Articulate how one's own developing skills in science and technology can be increasingly used in constructive community service or engagement that recognizes the potential impact on local and global issues, including environmental impact and sustainability.

Tailoring Your Education

The Mellon College of Science offers students tremendous opportunity for tailoring their education to meet individual professional objectives. Whether you target your degree to a particular field in your discipline via departmental options and concentrations, add a secondary major, minor, or degree to your primary degree program, participate in honors programs, or pursue a master's degree along with your bachelor's degree, MCS has much to offer you. Many of these opportunities are outlined below.

Departmental Concentrations

Each department in MCS offers degrees and programs that allow students to explore particular fields within a science discipline. These are outlined below — see the departmental sections for further details.

Biological Sciences

- Biochemistry
- Biophysics
- Cell Biology
- Computational Biology
- Developmental Biology
- Genetics
- Molecular Biology
- Neuroscience

Chemistry

- Biochemistry
- Biological Chemistry
- Colloids, Polymers, and Surfaces
- Computational Chemistry
- Environmental Chemistry
- Management
- Material Chemistry
- Polymer Science

Mathematical Sciences

- Computational and Applied Mathematics
- Computational Finance
- Discrete Mathematics and Logic
- Mathematics
- Operations Research
- Statistics

Physics

- Applied Physics
- Astrophysics
- Biological Physics
- Chemical Physics
- Computational Physics
- Quantum Physics

Minors, Double Majors, and Double Degrees

As an MCS student, you can pursue additional majors and minors to complement your primary degree, not only within the science college, but also through the other colleges at Carnegie Mellon. Carnegie Mellon offers many exciting interdisciplinary majors and minors, some of which are listed below. In addition, every college and most departments have designed minors or second majors in their discipline so that you can gain expertise in their fields as well.

Some students choose to gain this expertise by following a double degree program. This results in two distinct bachelor's degrees. Please see the section on Undergraduate Academic Regulations for a more formal definition of these "Multiple Degree" programs.

Interdisciplinary Majors and Minors

Here is a sampling of just a few of the interdisciplinary minors and majors offered at Carnegie Mellon (not all are in MCS). Please see the appropriate sections elsewhere in this catalog for specific descriptions and course requirements.

- Biological Sciences and Psychology Major
- Engineering Studies Minor
- Environmental and Sustainability Studies Additional Major or Minor
- Environmental Policy Major
- Health Care Policy and Management Minor
- International Affairs Minor
- Mathematics and Economics Major
- Neuroscience Major and Minor
- Operations Research Minor
- Robotics Minor
- Scientific Computing Minor
- Technology and Policy Minor

For a complete list of the minors offered at Carnegie Mellon, please go to Undergraduate Options (http://coursecatalog.web.cmu.edu/aboutcmu/undergraduateoptions/#minorstext).

University Student-Defined Majors

With a well-thought proposal, you may be able to pursue a major you have designed to meet your particular interests and goals. Please see the catalog section on Student-Defined Majors (http://coursecatalog.web.cmu.edu/aboutcmu/undergraduateoptions/#studentdefinedmajortext). MCS students wishing to pursue a student-defined major should contact the MCS Associate Dean for Undergraduate Affairs (https://www.cmu.edu/mcs/undergrad/advising/).

General Education Requirements

Students pursuing any MCS bachelor's degree will fulfill the 15 Core Education outcomes (p. 560) through their primary MCS major and by completing the following technical and nontechnical breadth requirements prior to graduation. Please see MCS Course Planning Guide (https://www.cmu.edu/mcs/undergrad/course-planning.html) for the recommended timeline to complete these requirements.

Technical Breadth Requirements

As a 21st Century practicing scientist or mathematician, our graduates will work with others from a variety of technical backgrounds. Therefore, all of our students will be broadly trained within the technical fields of science and math. Students will fulfill this training by completing four (4) technical courses in the Science, Technology, Engineering, and/or Mathematics (STEM) fields at Carnegie Mellon University.

A student must take at least 9 units, outside of their primary major department, from each of four categories listed below. These may include prerequisite courses or courses required by their major department but must be outside their home department. AP/IB/Cambridge credit may NOT be used to fulfill these requirements. At least three of these courses must be taken in their first year. The categories are:

A. Life Sciences

(Refer to your specific department for how this category should be fulfilled. Some courses have prerequisites that can be satisfied by AP, IB, Cambridge A Level Exams. Please check the prerequisites requirements as necessary.)

LIFE SCIENCES		
02-250	Introduction to Computational Biology	12
02-261	Quantitative Cell and Molecular Biology Laboratory	9
03-117	Frontiers, Analysis, and Discovery in Biological Sciences	6
03-121	Modern Biology	9
03-151	Honors Modern Biology	10
03-124	Modern Biology Laboratory	9
03-125	Evolution	9
03-132	Basic Science to Modern Medicine	9
03-133	Neurobiology of Disease	9
03-135	Structure and Function of the Human Body	9
03-161	Molecules to Mind	9
03-231	Honors Biochemistry	9
or 03-232	Biochemistry I	
42-101	Introduction to Biomedical Engineering	12
42-202	Physiology	9
85-219	Foundations of Brain and Behavior	9

B. Physical Sciences

(Refer to your specific department for how this category should be fulfilled. Some courses have prerequisites that can be satisfied by AP, IB, Cambridge A Level Exams. Please check the prerequisites requirements as necessary.)

PHYSICAL SCIENCES		
09-105	Introduction to Modern Chemistry I	10
09-106	Modern Chemistry II	10
09-107	Honors Chemistry: Fundamentals, Concepts and Applications	10
09-111	Nanolegos: Chemical Building Blocks	9
09-214	Physical Chemistry	9
09-217	Organic Chemistry I	9

09-219	Modern Organic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-225	Climate Change: Chemistry, Physics and Planetary Science	9
09-348	Inorganic Chemistry	10
33-121	Physics I for Science Students	12
33-122	Physics II for Biological Sciences & Chemistry Students	9
33-141	Physics I for Engineering Students	12
33-142	Physics II for Engineering and Physics Students	12
33-151	Matter and Interactions I	12
33-152	Matter and Interactions II	12
33-211	Physics III: Modern Essentials	10
33-224	Stars, Galaxies and the Universe	9
33-225	Quantum Physics and Structure of Matter	9

C. Mathematics, Statistics, and Computer Science

(Refer to your specific department for how this category should be fulfilled. Some courses have prerequisites that can be satisfied by AP, IB, Cambridge A Level Exams. Please check the prerequisites requirements as necessary.)

MATH, STATS, and CS		
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-124	Calculus II for Biologists and Chemists	10
21-127	Concepts of Mathematics	12
21-128	Mathematical Concepts and Proofs	12
21-228	Discrete Mathematics	9
21-241	Matrices and Linear Transformations	10
or 21-240	Matrix Algebra with Applications	
or 21-242	Matrix Theory	
21-259	Calculus in Three Dimensions	10
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
21-260	Differential Equations	9
or 21-261	Introduction to Ordinary Differential Equations	
36-200	Reasoning with Data	9
36-202	Methods for Statistics & Data Science	9
36-220	Engineering Statistics and Quality Control	9
36-225	Introduction to Probability Theory	9
36-309	Experimental Design for Behavioral & Social Sciences	9
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
15-122	Principles of Imperative Computation	12
15-150	Principles of Functional Programming	12
15-251	Great Ideas in Theoretical Computer Science	12

D. STEM Course

- All of the above courses
- Any introductory engineering course from CIT
- A STEM course approved by an MCS advisor

Technical Breadth-Departmental Requirements

Some of the majors in MCS require certain courses from the technical breadth requirement that are necessary for either prerequisite knowledge in the major or scientific breadth. For each of the four majors in MCS the Technical Breadth Requirement is completed as follows. If these requirements are met by AP/IB/Cambridge A Level Exams, students can choose any course from the categories to fulfill the Technical Breadth Requirement.

Biological Sciences

1. Life Sciences: any courses in this category **except** for the 03-XXX courses
2. Physical Sciences: 09-105, 09-106, 33-121 and 33-122
3. Math/CS/Stats: 21-120 and (21-122 or 21-124)
4. STEM Elective: will be filled by courses above or any STEM course from the approved list.

Chemistry

1. Life Sciences: 03-121 or 03-231 or 03-232
2. Physical Sciences: 33-121 and 33-122
3. Math/CS/Stats: 21-120 and (21-122 or 21-124)
4. STEM Elective: will be filled by courses above or any STEM course from the approved list.

Mathematical Sciences

1. Life Sciences: any courses in this category
2. Physical Sciences: any course in this category
3. Math/CS/Stats: any course in this category **except** for the 21-XXX courses, 36-200 Reasoning with Data, or 36-202
4. STEM Elective: any STEM course from the approved list.

Physics

1. Life Sciences: 03-121
2. Physical Sciences: 09-105
3. Math/CS/Stats: 21-120, 21-122, 21-259
4. STEM Elective: will be fulfilled by courses above or any STEM course from the approved list.

Nontechnical Breadth Requirements

MCS aspires for all of our undergraduates to leave our campus with a strong sense of personal integrity, social responsibility, ethics, working with diverse others, global engagement, and personal health and well-being. The following nontechnical breadth requirements will require students to develop a personalized plan for their course selection and meta-curricular participation to maximize their CMU experience. Our graduates will be well trained to be life-long and life-wide learners that will lead the scientific community and the world at large.

All candidates for MCS bachelor's degrees must complete the following nontechnical breadth requirements:

A. First Year Courses:

The following three courses must be taken in the first year:

38-101	EUREKA!: Discovery and Its Impact	6
or 38-100	CATALYST - MCS First-Year Seminar	
76-101	Interpretation and Argument A total of nine units must be completed in order to fulfill this requirement	9
or 76-102	Advanced First Year Writing: Special Topics	
or 76-106	Writing about Literature, Art and Culture	
or 76-107	Writing about Data	
or 76-108	Writing about Public Problems	
99-101	Core@CMU	3

B. Science and Society Course:

This requirement must be completed no later than the penultimate semester. Any student who finds an appropriate Carnegie Mellon course not on the pre-approved elective list below that might fulfill this requirement should contact their home department's Director of Undergraduate Studies to review the course description to determine if it can be substituted. In addition, transfer courses will also be considered for this category. However, this course requirement *cannot* be satisfied with AP/IB/Cambridge exam credit.

- Option 1: Take 38-304 Reading and Writing Science
- Option 2: Take one of the pre-approved (https://www.cmu.edu/mcs/science-society/electives.html)electives (https://www.cmu.edu/mcs/science-society/electives.html)

Note: QBS students should plan to enroll in 38-301 PROPEL in spring of junior year to fulfill this requirement.

C. ENGAGE Courses:

The ENGAGE courses are self-directed learning opportunities (using the MyCORE online platform) designed to enhance students' engagement with wellness, the arts and community service. Please see the course description for information on when these courses should be taken:

ENGAGE COURSES		
38-110	ENGAGE in Service	1
38-220	ENGAGE in the Arts	2
38-230	ENGAGE in Wellness: Looking Inward	1

38-330	ENGAGE in Wellness: Looking Outward	1
38-430	ENGAGE in Wellness: Looking Forward	1

D. Cultural/Global Understanding Course:

Cultural or global understanding course(s) may be taken at any time. Nine (9) or more units from the following group of courses will fulfill this requirement. Any student who finds an appropriate Carnegie Mellon course not on the list below that might fulfill this requirement should contact their home department's Director of Undergraduate Studies to review the course description to determine if it can be substituted. Cultural and global understanding courses that are taken while studying abroad can be used to fulfill this category. In addition, transfer courses will also be considered for this category. However, this course requirement *cannot* be satisfied with AP/IB/Cambridge exam credit.

CULTURAL/GLOBAL UNDERSTANDING		
57-173	Survey of Western Music History	9
57-306	World Music	9
70-100	Global Business	9
70-342	Managing Across Cultures	9
76-217	Literature & Culture of the 20th and 21st Century	9
76-221	Books You Should Have Read By Now	9
76-232	Introduction to Black Literature	9
76-239	Introduction to Film Studies	9
76-241	Introduction to Gender Studies	9
76-287	Sex & Texts	9
76-386	Language & Culture	9
79-112	Introduction to Asian American History	9
79-145	Genocide and Weapons of Mass Destruction	9
79-160	Introduction to the History of Science	9
79-170	Introduction to Science, Technology, and Society	9
79-175	Moneyball Nation: Data in American Life	9
79-189	Democracy and History: Thinking Beyond the Self	9
79-201	Introduction to Anthropology	9
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-203	The Other Europe: The Habsburgs, Communism, & Central/Eastern Europe, 1740-1990	9
79-205	20th Century Europe	9
79-208	Witchcraft and Witch-Hunting	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-229	The Origins of the Palestinian-Israeli Conflict, 1880-1948	9
79-230	The Arab-Israeli Conflict and Peace Process Through 1948 to Present	9
79-232	Arabian Peninsula Environmental History	9
79-234	Technology and Society	9
79-237	Comparative Slavery	9
79-240	Development of American Culture	9
79-242	African American History: Reconstruction to the Present	9
79-244	Women in American History	9
79-245	Capitalism and Individualism in American Culture	9
79-257	Germany and the Second World War	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-263	Mao and the Chinese Cultural Revolution	9
79-264	Tibet and China: History and Propaganda	9
79-265	Russian History: Game of Thrones	9
79-266	Russian History and Revolutionary Socialism	9
79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-268	World War I: The Twentieth Century's First Catastrophe	9
79-275	Introduction to Global Studies	9
79-278	How (Not) to Change the World	9
79-280	Coffee and Capitalism	9
79-281	Introduction to Religion	9
79-283	Hungry World: Food and Famine in Global Perspective	9
79-343	Education, Democracy, and Civil Rights	9
79-345	Roots of Rock & Roll	9
79-346	U.S. Political Films and Satire	9
79-350	Early Christianity	9
79-377	Food, Culture, and Power: A History of Eating	9
80-100	Introduction to Philosophy	9
80-101	Dangerous Ideas in Science and Society	9
80-130	Introduction to Ethics	9
80-180	Nature of Language: An Introduction to Linguistics	9
80-246	Moral Psychology	9
80-250	Ancient Philosophy	9
80-251	Modern Philosophy	9
80-252	Kant	9
80-253	Continental Philosophy	9
80-254	Analytic Philosophy	9
80-255	Pragmatism: Making Ideas Work	9
80-271	Mind and Body: The Objective and the Subjective	9
80-276	Philosophy of Religion	9
82-xxx	Any course from Languages, Cultures, and Applied Linguistics *Please note the category requirement is for 9+ units. Depending on the selected course you may need to take 1 or more courses together.	Var.
84-226	International Relations	9
84-275	Comparative Politics	9
84-306	Latin American Politics	9
84-319	Civil-Military Relations	9
84-322	Nonviolent Conflict and Revolution	9
84-323	War and Peace in the Contemporary Middle East	9
84-324	The Future of Democracy	9
84-325	Contemporary American Foreign Policy	9
84-328	Military Strategy and Doctrine	9
84-362	Diplomacy and Statecraft	9
84-365	The Politics of Fake News and Misinformation	9
84-370	Nuclear Security & Arms Control	9
84-372	Space and National Security	9
84-373	Emerging Technologies and International Law	9
84-380	US Grand Strategy	9
84-387	Remote Systems and the Cyber Domain in Conflict	9
84-389	Terrorism and Insurgency	9
84-390	Social Media, Technology, and Conflict	9
84-405	The Future of Warfare	9
85-350	Psychology of Prejudice	9
85-352	Evolutionary Psychology	9
88-221	Markets, Democracy, and Public Policy	9
88-234	Negotiation: International Focus	9

***Please note the units on the following course options. You may mix and match these courses together to meet the 9-unit minimum.**

57-209	The Beatles	6
79-216	Genghis Khan and the Mongol Empire	3
79-220	Screening Mexico: Mexican Cinema, 1898 to Present	6
79-222	China and the Second World War	6
79-238	Modern African American Film: History and Resistance	6
79-319	India Through Film	6
79-355	Fake News: "Truth" in the History of American Journalism	6
79-375	Science & Religion	6
82-xxx	Any course from Languages, Cultures, and Applied Linguistics	Var.
99-3xx	Any of the Country Today courses	3

E. Nontechnical Elective Courses

To fulfill this requirement, students must complete a minimum of four (4) nontechnical courses totaling at least 36 units in the College of Fine Arts, the Tepper School of Business, and/or the Dietrich College for Humanities and Social Sciences. A maximum of 18 units of these units may be fulfilled via AP/IB/Cambridge exam credit. Up to 36 units of these nontechnical elective units may be filled by transfer credit (with prior approval through the MCS transfer credit process).

Notes:

1. Courses counted toward the Cultural/Global Understanding requirement and the First-Year Writing requirement **do not** count toward this requirement.
2. Check our web site for courses from DC, CFA, and Tepper that may NOT be used (http://www.cmu.edu/mcs/undergrad/advising/hss-finearts/deletions.html) to satisfy this requirement because they are too technical in nature, plus a list of courses in other colleges (including SCS, CIT, and Heinz College) that do satisfy (http://www.cmu.edu/mcs/undergrad/advising/hss-finearts/additions.html) this requirement.
3. Mix and match nontechnical courses with less than 9 units either from an approved college (as specified above) or the additions list (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/additions.html) as long as the combined total is at least 36 units.

The following requirements apply to all MCS bachelor's degrees:

1. Students must complete a minimum of 360 units.
2. The four courses required for the Technical Breadth category can be completed at Carnegie Mellon or via transfer credit.
3. AP/IB/Cambridge exam credit cannot be used to fulfill the Science and Society Requirement. Transfer courses will also be considered for this category.
4. AP/IB/Cambridge exam credit cannot be used to fulfill the Cultural/Global Requirement. Cultural and global understanding courses that are taken while studying abroad can be used to satisfy this requirement. In addition, transfer courses will also be considered for this category.
5. For the Nontechnical Electives requirement, students must complete a minimum of four courses totaling at least 36 units with a maximum of 18 units from AP/IB/Cambridge exam credit. In addition, transfer courses will also be considered for this category.

Double Counting Restrictions

Double counting occurs when a student attempts to use one course to meet more than one major, college, or university degree requirement. Any student attempting to double count a course should only do so in close consultation with all relevant academic advisor(s) and/or the Assistant Dean for Educational Initiatives to ensure that all degree requirements are appropriately met.

Generally speaking, students are permitted to double count courses from the MCS Core Education requirements towards their primary major, additional major, or additional minor requirements. However, the following information describes limitations to double counting policies within the MCS Core Education requirements themselves.

The goals of the MCS core technical breadth requirements are different from the goals of the non-technical breadth requirements. Therefore, students are not permitted to double count courses across the following categories/courses:

1. Technical Breadth Requirements (students must take 4 courses total, 1 each from the life sciences, physical sciences, and math, statistics and computer science).

2. Non-Technical Breadth Requirements (including the first-year seminar, first-year writing requirement, ENGAGE courses, third year seminar, cultural/global understanding requirement, and non-technical breadth requirements).

Furthermore, students are not permitted to double count courses across the following list of non-technical core requirements.

1. First-Year Writing Requirement

2. Global/Cultural Understanding Requirement

3. Science and Society Requirement

4. Non-Technical Breadth Requirements (36 units total)

Honors Degree Programs in MCS

Several of the departments in MCS offer students an opportunity to participate in a departmental honors degree program. Some of these programs result in a master's degree along with the bachelor's degree (see next section on accelerated master's programs). These programs are listed below; see the department's section of the catalog for more details.

- Honors Program in Research Biology
- Departmental Honors in Chemistry
- Honors B.S./M.S. Program in Chemistry
- Honors B.S./M.S. Program in Mathematical Sciences

Accelerated Master's Programs

Carnegie Mellon offers some accelerated master's programs for motivated students, whereby students complete both the bachelor's and the master's degree in four or five years. Some programs are in the student's home department in MCS as part of an honors program, while others are offered through one of our graduate schools at Carnegie Mellon. Below is a listing of the programs currently available to MCS students; please see the appropriate sections of the catalog for more details.

- Honors B.S./M.S. Program in Chemistry
- Honors B.S./M.S. Program in Mathematical Sciences
- Accelerated Master's Program in the Heinz College

Study Abroad

There are many programs for studying abroad, usually during your junior year. Please see the catalog section on Undergraduate Options for more details, and talk with the Office of International Education to get information and advice specifically for you.

Pre-Professional Programs

Many students in the Mellon College of Science decide to pursue professional training such as medical school or law school after completing their undergraduate work. Carnegie Mellon offers strong advising services to support these students. Through these programs, students get help with everything from course selection to identification of important experiential opportunities to the application process itself.

Health Professions Program

Faculty Contact: Jason D'Antonio

Please see the Undergraduate Options (http://coursecatalog.web.cmu.edu/aboutcmu/undergraduateoptions/#healthproftext) section for details on the Health Professions Program.

Pre-Law Advising Program

Faculty Contact: Joseph Devine

Please see the Undergraduate Options (http://coursecatalog.web.cmu.edu/aboutcmu/undergraduateoptions/#prelawtext) section for details on the Pre-Law Advising Program.

Intercollege Programs

Bachelor of Science and Arts Degree Program (BSA)

Students in the Bachelor of Science and Arts Degree Program (http://coursecatalog.web.cmu.edu/servicesandoptions/intercollegeprograms/bxaintercollege/.html) are jointly admitted to MCS and the College of Fine Arts (CFA). This is a degree program for students who are naturally gifted in both the arts and the sciences, and allows for the combining of talents in these areas.

Additional Major in Environmental and Sustainability Studies

The Dietrich College of Humanities & Social Sciences and the Mellon College of Science have joined together to establish the interdisciplinary Program in Environmental & Sustainability Studies offering a Minor or an Additional Major. Please see the Intercollege section (p.) of the catalog for requirements of these programs.

Applying Your Education Through Research

An important feature of education in MCS is the opportunity for undergraduate research experience. This experience may be arranged as a course taken for credit or occasionally as a part-time job. Our website (https://www.cmu.edu/mcs/) offers a range of useful information including links to faculty research areas, links to undergraduate research programs at other institutions, and ideas on how to get involved. Because of the strong research base of MCS, undergraduate research positions offer an exciting opportunity to apply your theoretical training to participate in the discovery of new knowledge.

Students can earn MCS Research Honors for significant research accomplishments; see the policy outlined below for the requirements.

Mellon College of Science Research Honors

Undergraduates in the Mellon College of Science will be awarded MCS College Honors at the completion of their degree if they have met one of these requirements:

1. Successfully completed the Honors BS/MS program in the Department of Chemistry or Department of Mathematical Sciences.
2. Successfully completed the departmental honors program in the Department of Biological Sciences or the Department of Chemistry.
3. Earned a cumulative grade point average of ≥3.20 (by the end of their seventh semester or by the time of graduation) and carried out significant research. Typically, this would consist of an academic project carried out for at least two semesters. However, a single project that spans a summer and a semester or that the research mentor deems to be significant and sustained, even if the student worked for pay rather than credit, will be allowed. In addition, some form of public dissemination of this research, which has been approved by the MCS Associate Dean for Undergraduate Affairs, such as a peer reviewed publication, research thesis, or presentation at an external scientific meeting is required. The Meeting of the Minds by itself is not sufficient and participation in a pre-approved judged competition (eg. Sigma Xi, Math Department competition, or Psychology department competition) is necessary.

Final approval of nominations for MCS Honors will come from the Dean of MCS and the MCS Associate Dean for Undergraduate Affairs. Students can apply to their primary departmental advisor using this form on the MCS website: https://www.cmu.edu/mcs/undergrad/advising/college-research-honors.html.

Research Centers

The Mellon College of Science is home to a number of innovative research centers. These centers are particularly strong because of the interdisciplinary collaboration of their scientists. This interdisciplinary research brings international prestige to the college. Many students conduct undergraduate research with one of these centers.

The Bruce and Astrid McWilliams Center for Cosmology joins research efforts in astrophysics and particle physics and partners with computer science, statistics, and other disciplines to unravel the mysteries of the universe.

The Center of Atmospheric Particle Study's goal is to be the world leader in science, engineering, and policy covering the full role of fine particulate matter in the atmosphere. Our goal in research is to advance the state of knowledge across this spectrum substantially, to provide both policy-relevant research, and to participate directly and actively in the evolution of environmental policy related to particulate matter.

The Center for Computational Finance's mission is to improve the interaction between academic research and the finance industry.

The Center for Macromolecular Engineering's goals are to enhance the benefits of polymer science to society by developing new methods to prepare advanced polymer materials, train and develop tomorrow's scientists, and transfer technology to industry.

The Center of Nano-enabled Device and Energy Technologies' mission is to work on real-world problems that can be solved potentially with appropriate nano-enabled technologies.

The Center for the Neural Basis of Cognition is a joint program between Carnegie Mellon University and the University of Pittsburgh. It synthesizes the disciplines of basic and clinical neuroscience, cognitive psychology, and computer science, combining neurobiological, behavioral, computational, and brain imaging methods.

The Center for Nonlinear Analysis was established in 1991. A special focus for applications emphasizes new and innovative methods to study contemporary issues in materials science. The center has created a vigorous environment for collaboration among mathematical and allied scientists.

The Center for Nucleic Acids Science and Technology is a community of Carnegie Mellon scientists and engineers unified by interests in the chemistry, biology, and physics of DNA, RNA, and PNA (peptide nucleic acid).

The Institute for Green Science has been established as a research, education, and development center in which a holistic approach to sustainability science is being developed. The focus of the institute is in three areas: renewable energy technologies, chemical feedstocks, and benign alternatives to polluting technologies.

The Pittsburgh Supercomputing Center provides information on advanced scientific computing for engineering and research.

Academic Standards

MCS Dean's List

Each semester MCS recognizes those students with outstanding academic records by naming them to the Dean's List. The criteria for such recognition are as follows:

Dean's List

The student must earn a quality point average of at least 3.50 while completing a minimum of 36 factorable units and earning no incomplete grades.

Dean's List with High Honors

The student must earn a quality point average of at least 3.75 while completing a minimum of 36 factorable units and earning no incomplete grades.

Academic Actions

In order to maintain good academic standing, students from the Mellon College of Science must attain at least minimum quality point averages for each semester (as well as cumulatively), and also make and maintain adequate progress toward completing their degree requirements. "Adequate progress towards graduation" generally means that students are successfully completing an average of 45 units per semester so that at the end of eight semesters they will have accumulated the minimum of 360 units required for graduation, have a cumulative QPA of at least 2.00, and completed all college General Education and primary major course requirements.

Specifically, MCS students will make satisfactory academic progress if they meet the following criteria:

- The semester GPA is ≥ 2.00.
- The cumulative QPA is ≥ 2.00.
- A student maintains full-time status (≥ 36 units) after the 10th day of classes in a semester.
- Completing ≥80% of attempted units in a semester (calculated using total units carried when grades are entered). Grades of N, W, or R grade do not count as completed units.

When a student fails to meet minimum performance criteria, it normally results in an "academic action." Depending on the circumstances, one of the following actions is taken: Academic Warning, Continued Academic Warning, Suspension, or Drop. These academic actions are recommended by the college's departments based on the guidelines described below. However, the sequence of the academic actions is not automatic in all cases.

Academic actions are not meant to be punitive and are put into place to support student success. These actions are designed to notify students of specific academic requirements, outline goals for completion, and identify avenues of support to help students succeed. Students on academic action (except drop) will be asked to identify a plan of action to use resources to improve their academic performance. Resources can include the Student Academic Success Center, CaPS, UHS, and/or regular meetings with advisors, among others.

Warning

The action of Warning will be taken if in any semester a student fails to make satisfactory academic progress as defined above.

The term of Warning is one semester as a full-time student. Students on academic probation may not overload above 54 units in the semester of Warning.

A student is occasionally continued on Warning who has had one semester on Warning and is not yet in good academic standing (as defined above) but whose record indicates that the standards are likely to be met at the end of the next semester of study.

Suspension

A student who does not meet minimum standards at the end of one semester of Warning will be suspended. The minimum period of suspension is one academic year (two semesters). At the end of that period a student may return to school on final academic Warning by:

- Receiving permission in writing from the MCS Associate Dean for Undergraduate Affairs.
- Completing a Return from Leave form from Enrollment Services (https://www.cmu.edu/hub/registrar/leaves-and-returns/).
- Providing transcripts and clearance forms if the student has been in a degree program at another college or university, even though academic credit earned will not transfer to Carnegie Mellon unless prior approval has been granted by the MCS Associate Dean for Undergraduate Affairs.

Students on suspension can review a list of available resources on the HUB's website (https://www.cmu.edu/hub/registrar/leaves-and-returns/access.html). A student who has been academically suspended and who is not employed by the University must absent themselves from campus and is, for the term of the suspension, barred from all activities and affiliations that stem from one's status as an enrolled student. These include registering or enrolling for courses, sitting in on classes, living in residence halls or Greek houses, membership and participation in student activities, and employment in student jobs. (NOTE: Exceptions to the restriction from student jobs for students on academic suspension will in general be granted for summer employment if the position was accepted prior to the decision to suspend.)

Notably, employment within the university in non-student jobs is possible for students on academic suspension, subject to the hiring criteria of the hiring department. However, a student on academic suspension wishing to accept a job on campus must speak with the Associate Dean of the student's college to ensure that the employment will not constitute a violation of the terms of suspension. The Associate Dean will generally allow such employment, in consultation with the Dean of Student Affairs. One employment benefit not available to students on academic suspension who accept a full-time job with the University is the option to take courses through tuition remission. The option to take courses becomes available only after the academic suspension is over.

Students returning from suspension should plan to work with their advisor and Associate Dean for undergraduate affairs at least 30 days prior to the semester they plan to return. Ideally, students will connect with the Associate Dean several weeks before registration for the semester of planned return. In addition to the steps for a smooth return (https://www.cmu.edu/hub/registrar/leaves-and-returns/) described on the Registrar's website, MCS students should prepare a short (1000 word maximum) essay describing how they've been preparing for a successful return to CMU.

Upon return, students will be on **Final Academic Warning**. Students in this situation must work closely with all available resources (particularly their academic advisor) to ensure all resources are being properly used to maximize success to avoid progression to academic drop. Students returning on Final Academic Warning may not overload above 54 units in the semester of return.

Drop

This is a permanent severance from the Mellon College of Science. Students are dropped when it seems clear that they will not be able to meet minimum standards. A student who has been suspended and who fails to meet minimum standards after returning to school is dropped.

A student who has been academically dropped and who is not employed by the University must absent themselves from campus and is barred from all activities and affiliations that stem from one's status as an enrolled student. These include registering or enrolling for courses, sitting in on classes, living in residence halls or Greek houses, membership and participation in student activities, and employment in student jobs. (NOTE: Exceptions to the restriction from student jobs for students on academic drop will in general be granted for summer employment if the position was accepted prior to the decision to drop.)

Appeals of Academic Actions

In accordance with the Appeal of Academic Actions Policy (https://www.cmu.edu/student-affairs/theword/academic/appeal-of-grades-and-academic-actions.html) outlined in The Word student handbook:

"If a student believes an academic action is inconsistent with the policies of the college, a student should:

1. Submit a formal written appeal to the Associate Dean of the college responsible for the decision, with a copy to the dean, requesting review of the action including all relevant materials to substantiate the inconsistency in policy and to support their concerns. Appeals are due within 10 days of the date the student is notified of the action.
2. The Dean of the college, or the dean's designate, will review the appeal and issue a decision and the basis for it within 30 days.

If, after carrying out the steps of either process described above, the student believes that the matter has not been adequately resolved, or if no decision has been rendered by the appropriate date, the student may appeal at the university level. To appeal at the university level, the student must present copies of all documents and a formal letter of appeal to the provost. Appeals to the Provost office are due within 5 days of a decision from the student's college-level appeal. The Provost or another designated university officer will respond in writing with a final resolution, including the basis for it, within thirty (30) days, or as soon thereafter as practical."

Course Overloads

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Overloading is defined as taking more than the equivalent of five
 full-semester courses in one semester; for MCS students overload
 means registering for more than 54 units in one semester.
Eligibility to overload is defined as:
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1. Student must be in good academic standing (not on any academic action listed above).
2. Student must have a QPA of at least 3.25 in the last completed semester or student must have a current cumulative QPA of at least 3.25.
3. Students new to the college and university (i.e., first-year students and new external transfer students from outside of CMU) may not overload during their first Carnegie Mellon semester.
4. Advisors can, in accordance with these policies, approve overloads up to 61 units. Associate Dean approval is required for overload requests over 61 units. In addition to the other criteria listed above, students must have also successfully completed ≥45 units in a previous semester to request to overload >61 units.

Eligibility to overload based on QPA does not automatically allow the student to register for an overload. Rather, students must petition and discuss the proposed overload with their primary academic advisor. The discussion will include the reason for overload (additional major/minor, trying to graduate early, etc.). If approved, the academic advisor will increase the student's unit maximum for the relevant semester.

The first opportunity to register for a course overload is after registration week for the proposed overload semester. Registration week for the spring semester is usually the third week in November; for the fall semester, it is usually the third week in April. Consult the official university academic calendar for the exact dates.

If as a result of final grades for the current semester a student approved to overload for the next semester falls below the overload eligibility criteria listed above, the academic advisor may withdraw the overload permission. Students thus affected are responsible for resolving this in consultation with their academic advisor.

Students may appeal their advisor's overload request decision to the Associate Dean for Undergraduate Affairs in writing (email is appropriate for this petition, but a meeting may be requested by the Associate Dean to discuss the appeal).

Transfer into MCS Departments

This section describes the variety of entry points into the Mellon College of Science for students already admitted to a university (Carnegie Mellon or another university). All prospective students not already enrolled should contact the Office of Admission for details about the application process for Carnegie Mellon University.

General Internal Transfer Information:

MCS does not accept undeclared internal transfer students. Students will need to declare which major they intend to pursue upon transfer into MCS at the time of application. The list of prerequisite courses for each department are listed below. *Students will not be considered for transfer on the basis of AP/IB/Cambridge scores alone*. Applicants may use AP/IB/Cambridge credit as prerequisites to the courses listed below prior to applying for transfer but must have completed at least one prerequisite course at CMU.

Applications are accepted on a rolling basis. Students applying for transfer into MCS must have approval from the new department (through the director of undergraduate studies/affairs in the MCS department) and from the MCS Associate Dean for Undergraduate Affairs. Students can complete the application for transfer (https://www.cmu.edu/mcs/undergrad/advising/forms/mcs_transfer_or_additional_degree.pdf) with the MCS departmental program director. Students will be considered for transfer on the basis of available space and the student's academic performance in coursework related to their intended MCS major.

Students should complete the prerequisite requirements of their intended department prior to applying for internal transfer:

- Potential transfer students into the **Department of Biological Sciences** must have completed 03-121 Modern Biology or 03-220 Genetics AND 09-105 Introduction to Modern Chemistry I with a C grade or better.
- The **Chemistry Department** requires students wishing to transfer to complete and have earned the following grades in one of the following options at CMU:
  - an A in 09-107 or
  - have C grade or better in 09-105 or 107 AND a C grade or better in 09-106 (at CMU) or
  - have a C grade or better in 09-217 or 09-219.
- Students wishing to transfer into the **Physics Department** must have earned a C grade or better in one of the following classes completed at CMU: 33-121, 33-151, 33-141, 33-142, 33-152, or 33-211 AND have earned a C grade or better in one of the following classes completed at CMU: 21-120, 21-122, or 21-259.
- Students wishing to transfer into the **Department of Mathematical Sciences** must have completed 21-127 Concepts of Mathematics or 21-128 Mathematical Concepts and Proofs AND 21-241 Matrices and Linear Transformations or 21-242 Matrix Theory with a B grade or better in both courses as well as an overall QPA of 3.5 or higher.

Students entering MCS or already declared in MCS:

Entering undergraduate students admitted to MCS can choose to pursue any major within MCS. This choice is usually made prior to the first semester of the sophomore year (normally during the second semester of the first year) and does not require approval by any department. While it is possible to remain undeclared beyond the first year, declaring a major offers access to departmental resources, advising, and course reservations.

Students who have declared a major in MCS and wish to transfer into another department within MCS must meet the prerequisites listed above and have approval from the relevant department program director for their intended major (see the internal transfer form (https://www.cmu.edu/mcs/undergrad/advising/forms/mcs_transfer_or_additional_degree.pdf) for details) and from the MCS Associate Dean for Undergraduate Affairs. Students wishing to transfer into a department in MCS beyond the first semester will be considered for transfer on the basis of available space and the student's academic performance in coursework related to their intended MCS major.

Students enrolled in another college at Carnegie Mellon:

Undergraduate students admitted to colleges other than MCS and wishing to transfer into an MCS department should consult with the relevant department program director for their intended major (see the internal transfer form (https://www.cmu.edu/mcs/undergrad/advising/forms/mcs_transfer_or_additional_degree.pdf) for details) and obtain approval from the MCS Associate Dean for Undergraduate Affairs. Students must meet the prerequisites of their intended department (listed above). Students may submit an internal transfer request no earlier than the first day of their second semester.

Undergraduate students not in MCS and wishing to transfer into a department in MCS will be considered for transfer on the basis of available space and the student's academic performance in coursework related to their intended MCS major.

Students wishing to transfer from another university into an MCS department:

A student first applies through the Office of Admission. If the Office of Admission believes the applicant is acceptable, the student's record is sent to the appropriate department for evaluation and a decision on acceptance. Students will be considered for transfer on the basis of available space and the student's academic performance in coursework related to their intended MCS major.

Graduation Requirements

To be eligible to graduate, undergraduate students must complete all course requirements for their program with a cumulative Quality Point Average of at least 2.00 for all courses taken. \ Some programs may have additional QPA requirements in order to graduate. Students are encouraged to confirm all graduation requirements with their academic advisor.

A minimum of 360 units must be completed. This will include the MCS Core Courses (technical and nontechnical electives) and all departmental course requirements.

Students will be required to meet the residency requirement and to have met all financial obligations to the university before being awarded a degree. The residency requirement is detailed in the Academic Regulations section of the catalog. A student may seek permission to modify graduation requirements by petition to the MCS College Council.

Graduation Honors

There are two types of honors awarded at graduation.

University Honors

University Honors are automatically awarded to students who have earned a cumulative Q.P.A. of 3.5 or better after either seven semesters or by the time they are certified for graduation.

College Research Honors

Please see the section "Mellon College of Science Research Honors (p. 564)" for information on how to qualify for College Research Honors.

Faculty

MAGGIE BRAUN, Associate Dean for Undergraduate Affairs – Ph.D. ,

JASON D'ANTONIO, Director of Health Professions Program – Ph.D.,

KENNETH HOVIS, Assistant Dean for Educational Initiatives – Ph.D.,

MANFRED PAULINI, Associate Dean for Graduate and Faculty Affairs – Ph.D.,

MICHAEL YOUNG, Associate Dean for Diversity – Ph.D.,

Administration

KRYSTALYN KOVACS, Undergraduate Programs Coordinator, HPP

ABIGAIL PINNOW, Undergraduate Programs Administrator, MCS

TARA PRIMIERO, Senior Academic Advisor, MCS

Department of Biological Sciences

Veronica Hinman, Department Head

Amanda Willard, Director of Undergraduate Studies

Location: Doherty Hall 1321
www.cmu.edu/bio (http://www.cmu.edu/bio/)

A major revolution is occurring in the field of biological sciences. Biology is undergoing unprecedented technological advances in biochemistry, biophysics, cell biology, genetics, molecular biology, developmental biology, neuroscience and computational biology. Carnegie Mellon's Department of Biological Sciences is nationally recognized as one of the outstanding departments in these areas. Advances in basic research are already being used to solve problems, not only in medicine and public health, but also in areas such as agriculture, forestry, mining, energy, and in industrial and pharmaceutical manufacturing processes. The department provides its students with an education that has both intellectual breadth and depth of exposure to modern research biology. This education can be used to gain employment immediately after graduation in government, industry or academic research laboratories, or to pursue graduate studies in a variety of areas such as science, medicine, public health, law, or business. A degree in biological sciences provides excellent preparation for medical school or other graduate programs in the health professions. These students are aided by the Carnegie Mellon Health Professions Program (HPP), an advisory and resource service for all Carnegie Mellon students who are considering careers in the health care field. (See the HPP (p.) section in this catalog or www.cmu.edu/hpp (http://www.cmu.edu/hpp/) for more information.)

The department offers a Bachelor of Science (B.S.) degree in Biological Sciences. This program has a distinctive core curriculum that provides a foundation in biology, chemistry, computer science, mathematics, and physics. In addition to the core courses, the program includes six biology electives, free electives as well as humanities, social science and fine arts electives. With these electives, students can shape a degree program according to their own interests and career goals. For students who have an interest in a particular field of biology and wish to have a specialized focus, the department offers options in biochemistry, biophysics, cell biology, computational biology, developmental biology, genetics, molecular biology and neuroscience that provide the relevant training in each area. The options are especially recommended for students who are considering graduate school in one of these areas.

In this exciting era that includes the influence of biology and the life sciences on many fields from medicine to law, the in-depth exposure to multiple disciplines provides opportunities for students to prepare for involvement at the forefront of emerging new fields, markets, and policy changes. The Department of Biological Sciences at Carnegie Mellon is working at these new interfaces through interdisciplinary research and educational programs. Innovative interdisciplinary degrees which are offered by the department include the inter-college B.S. degree in Neuroscience as well as the unified B.S. degree in Biological Sciences and Psychology. Students also pursue interests at the interface between the arts and sciences through the Bachelor of Science and Arts (B.S.A.) degree program combining biological sciences or neurobiology with a discipline in the College of Fine Arts. A stand-alone Bachelor of Arts (B.A.) degree is available for students who wish to expand their educational training into other fields. Many students choose to broaden their education by pursuing minors and additional majors in disciplines throughout the university, not just within the Mellon College of Science.

One of the most important features of the Department of Biological Sciences is the opportunity for undergraduate students to interact with faculty. Providing a solid foundation to scientific practice is critical; therefore, the department offers first-year students a variety of inquiry-based, hands-on courses that incorporate a wide range of topics and interests within Biological Sciences. These courses kick-start the transformation of science students to scientists. We encourage our students to get to know their faculty through one of these courses, or through mentored, independent research projects in the faculty laboratories. Our faculty members are prominent research scientists who also teach beginning and advanced courses. The upper level teaching laboratories are located in the same building as the faculty research laboratories and share scientific equipment. We encourage students to make themselves aware of the research areas of the faculty and to develop research projects with faculty. While such research is usually most important in the senior year, it may begin earlier in a student's undergraduate training. The department has an Honors Program in Research Biology to facilitate a more intensive involvement in research for eligible students. During the past four years, more than 85 percent of the undergraduate biology majors have worked with faculty on their research and, in some cases, have been co-authors of research papers and have given presentations at national meetings.

Since the fall of 2011, the Department of Biological Sciences has offered a B.S. degree in Biological Sciences at Carnegie Mellon University in Doha, Qatar. Students enrolled in this degree program will also complete the requirements outlined below. One of the required courses for the CMU-Qatar program is offered through a collaboration with the Weill Cornell Medical College in Qatar. For a listing of how the degree requirements are fulfilled for students enrolled in Doha, please consult the CMU-Qatar website (www.qatar.cmu.edu/curriculum-bs (https://www.qatar.cmu.edu/curriculum-bs/)).

Program Outcomes

Upon graduation recipients of the B.S. or B.A. degree in Biological Sciences will:

- Use the basic concepts and experimental, computational, and theoretical methods of the core fields of science, mathematics and technology.
- Use foundational knowledge from the natural sciences and mathematics for advanced work in the discipline.
- Understand and apply the scientific method.
- Apply disciplinary knowledge toward solving problems.
- Use modern methods for finding and sharing current scientific information and primary literature.
- Convey information including scientific content in written and oral formats within Biological Sciences.
- Work in multidisciplinary and culturally diverse teams.
- Demonstrate proper values and ethics within Biological Sciences, the University, and the larger scientific community.

B.S. Biological Sciences

The Bachelor of Science (B.S.) in Biological Sciences is built around a core program and elective units as detailed in the following section.

Degree Requirements:

Biological Sciences		Units
03-151	Honors Modern Biology	10
or 03-121	Modern Biology	
03-201	Undergraduate Colloquium for Sophomores	2
03-220	Genetics	9
or 03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	
03-231	Honors Biochemistry	9
or 03-232	Biochemistry I	
02-250	Introduction to Computational Biology	12
03-320	Cell Biology	9
03-343	Experimental Techniques in Molecular Biology	12
03-344	Experimental Biochemistry	12
or 03-345	Experimental Cell and Developmental Biology	
or 03-346	Experimental Neuroscience	
03-411	Topics in Research	1
03-412	Topics in Research	1
03-xxx	Biological Sciences Electives [1]	54
Total Biology units		**131**

[1] Details on electives can be found in the "Biological Sciences Electives" section (see below).

Mathematics, Physics and Computer Science		Units
15-110	Principles of Computing	10
or 15-112	Fundamentals of Programming and Computer Science	
21-120	Differential and Integral Calculus	10
21-124	Calculus II for Biologists and Chemists	10

or 21-122	Integration and Approximation	
33-121	Physics I for Science Students	12
or 33-141	Physics I for Engineering Students	
33-122	Physics II for Biological Sciences & Chemistry Students	9
or 33-142	Physics II for Engineering and Physics Students	
99-101	Core@CMU	3
Total Science units		**54**

Chemistry		Units
09-105	Introduction to Modern Chemistry I [2]	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-217	Organic Chemistry I	9
09-218	Organic Chemistry II	9
09-207	Techniques in Quantitative Analysis	9
09-208	Techniques for Organic Synthesis and Analysis	9
Total Chemistry units		**56**

[2] Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

Elective Units	Units
Free Electives	48
MCS Nontechnical Breadth Requirements [3]	72
Total Elective units	**120**

[3] For more information on the MCS Technical and Nontechnical Breadth Requirements, please refer to the MCS General Education Requirements (p. 561) section of this catalog. MCS Technical Breadth Requirements are all met through the required curriculum for the Biological Sciences degree (see below).

Minimum number of units required for degree: 360

MCS Technical Breadth Requirements

Majors entering CMU and majoring in Biological Sciences (or affiliated majors) in the Fall of 2015 or beyond will fulfill the MCS Technical Breadth requirements as follows:

1. Life Sciences: any courses in this category except for the 03-xxx courses. For the B.S. in Biological Sciences, this will be fulfilled by 02-250.
2. Physical Sciences: 09-105, 09-106, 33-121 and 33-122
3. Math/CS/Stats: 21-120 and (21-122 or 21-124)
4. STEM Elective: will be filled by courses above or any STEM course from the approved list.

Biological Sciences Electives

The following specifications apply to Biological Sciences electives:

- At least 18 units must be at the 03-3xx level or above, exclusive of 03-445 and 03-545 and interdisciplinary electives.
- Up to three interdisciplinary electives may count as general biology electives.
- Up to 18 units of 03-445 Undergraduate Research and/or 03-545 Honors Research may count as general biology electives; a maximum of 36 units of research can count for the minimum units required for graduation.
- Courses in biology taken through cross-registration or study abroad at another university may count as electives if prior permission is obtained from the Director of Undergraduate Studies.

Departmental Electives Group

03-113	Biologies in Text and Film *Offered only in Doha	9
03-117	Frontiers, Analysis, and Discovery in Biological Sciences	6
03-118	Beer: A Yeast's Perspective	6
03-119	Biology for Life Special Topics Micro	3
03-120	Biology for Life Special Topics Mini	Var.
03-124	Modern Biology Laboratory	9
03-125	Evolution	9
03-128	Biology for Life Special Topics	9
03-129	Human Health and Disease *Offered only in Doha	9
03-132	Basic Science to Modern Medicine	9
03-133	Neurobiology of Disease	9
03-135	Structure and Function of the Human Body	9
03-140	Ecology and Environmental Science	9
03-161	Molecules to Mind	9
03-230	Intro to Mammalian Physiology *Offered only in Doha	9
03-327	Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method	9
03-350	Developmental Biology	9
03-351	Computation and Biology Integrated Research Lab	9
03-360/02-319	Genomics and Epigenetics of the Brain	9
03-362	Cellular Neuroscience	9
03-363	Systems Neuroscience	9
03-365	Neural Correlates of Learning and Memory	9
03-366	Neuropharmacology: Drugs, Brain and Behavior	9
03-380	Virology *Offered only in Doha	9
03-390	Molecular and Cellular Immunology	9
03-391	Microbiology	9
03-410	Special Topics in Biological Sciences	Var.
03-435	Cancer Biology	9
03-439	Introduction to Biophysics	10
03-442	Molecular Biology	9
03-445	Undergraduate Research	Var.
03-451	Advanced Developmental Biology and Human Health	9
03-511	Computational Molecular Biology and Genomics	9
03-545	Honors Research	9
03-711	Computational Molecular Biology and Genomics	12
03-713	Bioinformatics Data Integration Practicum	6
03-727	Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method	12
03-728	Genome Editing Biotechnology	6
03-729	Entrepreneurship and protein-based drug development	6
03-730	Advanced Genetics	12
03-738	Synthetic Biology	6
03-740	Advanced Biochemistry	12
03-741	Advanced Cell Biology	12
03-742	Advanced Molecular Biology	12
03-751	Advanced Developmental Biology and Human Health	12
03-762	Advanced Cellular Neuroscience	12
03-763	Advanced Systems Neuroscience	12
03-766	Advanced Neuropharmacology: Drugs, Brain and Behavior	12
03-791	Advanced Microbiology	12
03-871	Structural Biophysics	12

Interdisciplinary Electives Group

Up to three of the following courses may count as general biology electives:

02-331	Modeling Evolution	12
02-425	Computational Methods for Proteogenomics and Metabolomics	9
02-450	Automation of Scientific Research	9
02-510	Computational Genomics	12
02-512	Computational Methods for Biological Modeling and Simulation	9
02-518	Computational Medicine	12
02-740	Bioimage Informatics	12
09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	9
09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	9
09-803	Chemistry of Gene Expression	12
21-127	Concepts of Mathematics	12
21-259	Calculus in Three Dimensions	10
21-260	Differential Equations	9
36-200	Reasoning with Data	9

42-202	Physiology	9
85-219	Foundations of Brain and Behavior	9

Options for the B.S. in Biological Sciences

Students who wish to specialize in a particular area of biology can do so through a set of departmentally defined options. Options are not required and need not be declared. The elective courses required for each of the options are listed below. Students can elect to complete a maximum of two options. Please discuss interest in these options with the Carnegie Mellon Department of Biological Sciences advisor to plan out any pre-requisite coursework and identify appropriate course alternatives in the event that a graduate-level course is not being offered during a particular academic year.

Biochemistry Option

Required Biology Electives:

03-740	Advanced Biochemistry	12
21-259	Calculus in Three Dimensions	9-10
or 21-260	Differential Equations	

Any ONE of the following courses:

09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	9
09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	9
09-521	Metals in Biology: Function and Reactivity	6

Recommended Biology Electives:

03-442	Molecular Biology	9
03-439	Introduction to Biophysics	10
03-871	Structural Biophysics	12

Biophysics Option

Required Biology Electives:

03-740	Advanced Biochemistry	12
03-439	Introduction to Biophysics	10
21-259	Calculus in Three Dimensions	9-10
or 21-260	Differential Equations	

Recommended Biology Electives:

03-871	Structural Biophysics	12

Cell Biology Option

Required Biology Electives:

03-350	Developmental Biology	9
03-741	Advanced Cell Biology	12

Any ONE of the following courses:

03-362	Cellular Neuroscience	9
03-390	Molecular and Cellular Immunology	9

Computational Biology Option

Required Biology Electives:

03-711	Computational Molecular Biology and Genomics	12
15-210	Parallel and Sequential Data Structures and Algorithms	12

Any ONE of the following courses:

36-200	Reasoning with Data	9
21-260	Differential Equations	9
21-241	Matrices and Linear Transformations	11

Recommended Biology Electives:

02-512	Computational Methods for Biological Modeling and Simulation	9
15-451	Algorithm Design and Analysis	12

Developmental Biology Option

Required Biology Electives:

03-350	Developmental Biology	9
03-442	Molecular Biology	9
03-751	Advanced Developmental Biology and Human Health	12

Recommended Biology Electives:

03-741	Advanced Cell Biology	12

Genetics Option

Required Biology Electives:

03-327	Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method	9
03-442	Molecular Biology	9
03-730	Advanced Genetics [6]	12

[6] Minimum grade of B in 03-220 required.

Recommended Biology Electives:

03-391	Microbiology	9

Molecular Biology Option

Required Biology Electives:

03-442	Molecular Biology	9
09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	9
03-727	Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method	12

Recommended Biology Electives:

03-390	Molecular and Cellular Immunology	9
03-391	Microbiology	9
03-730	Advanced Genetics	12

Neuroscience Option

Required Biology Electives:

03-362	Cellular Neuroscience [7]	9
03-363	Systems Neuroscience [7]	9

Any ONE of the following courses:

03-133	Neurobiology of Disease	9
03-350	Developmental Biology	9
03-365	Neural Correlates of Learning and Memory	9
03-366	Neuropharmacology: Drugs, Brain and Behavior	9
42-202	Physiology	9
85-219	Foundations of Brain and Behavior	9

[7] One of these courses must be completed at the Graduate Level (Complete either 03-762 or 03-763).

B.S. Biological Sciences/Neuroscience Track

The Bachelor of Science in Biological Sciences/Neuroscience Track provides an option for those Biological Sciences majors who are interested in an intensive curricular focus in neuroscience. The requirements of the Track are the same as those listed for the B.S. in Biological Sciences with the following changes to the biological sciences elective requirements:

Degree Requirements:

03-362	Cellular Neuroscience	9
03-363	Systems Neuroscience	9
03-365	Neural Correlates of Learning and Memory	9

Plus three of the following electives:

03-133	Neurobiology of Disease	9
03-350	Developmental Biology	9
03-360/02-319	Genomics and Epigenetics of the Brain	9
03-366	Neuropharmacology: Drugs, Brain and Behavior	9
15-385	Introduction to Computer Vision	6
15-386	Neural Computation	9

42-202	Physiology	9
85-211	Cognitive Psychology	9
85-213	Human Information Processing and Artificial Intelligence	9
85-219	Foundations of Brain and Behavior	9

B.S. Neuroscience

The Bachelor of Science in Neuroscience is listed in the Intercollege Programs (p. 891) section of this catalog. It is a joint degree program offered between the Mellon College of Science and the Dietrich College of Humanities and Social Sciences. Current MCS students interested in pursuing this degree should contact Biological Sciences Undergraduate Programs Office (bio-ungrad@andrew.cmu.edu).

B.S. Biological Sciences and Psychology

Veronica Hinman, *Department Head, Biological Sciences*

Susanne Ferber, *Department Head, Psychology*

This major is intended to reflect the interdisciplinary nature of current research in the fields of biology and psychology, as well as the national trend in some professions to seek individuals broadly trained in both the social and natural sciences.

Note: Students entering from the Dietrich College of Humanities and Social Sciences will earn a Bachelor of Science in Psychology and Biological Sciences. Students in the Mellon College of Science will earn a Bachelor of Science in Biological Sciences and Psychology.

Depending on a student's home college (DC or MCS), General Education (GenEd) requirements will be different. GenEd requirements for DC (p. 353) and MCS (p. 560) are found on their respective Catalog pages.

Degree Requirements:

Biological Sciences		Units
03-151	Honors Modern Biology	10
or 03-121	Modern Biology	
03-201	Undergraduate Colloquium for Sophomores *Only required for MCS Students	2
03-220	Genetics	9
or 03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	
03-231	Honors Biochemistry	9
03-320	Cell Biology	9
03-343	Experimental Techniques in Molecular Biology	12
03-411	Topics in Research	1
03-412	Topics in Research	1
03-xxx	General Biology Elective [1]	9
03-3xx	Advanced Biology Elective [1]	18
Total Biology units		**80**

[1] Please see description and requirements for electives under the B.S. in Biological Sciences section of this Catalog.

Mathematics, Statistics, Physics and Computer Science		Units
21-120	Differential and Integral Calculus	10
21-124	Calculus II for Biologists and Chemists	10
or 21-122	Integration and Approximation	
36-200	Reasoning with Data	9
36-309	Experimental Design for Behavioral & Social Sciences	9
or 85-309	Statistical Concepts and Methods for Behavioral and Social Science	
33-121	Physics I for Science Students [3]	12
or 33-141	Physics I for Engineering Students	
15-110	Principles of Computing	10-12
or 15-112	Fundamentals of Programming and Computer Science	
99-101	Core@CMU	3
Total Science units		**63-65**

[3] MCS students must also complete 33-122 Physics II for Biological Sciences & Chemistry Students.

Chemistry		Units
09-105	Introduction to Modern Chemistry I	10
09-106	Modern Chemistry II	10
09-217	Organic Chemistry I	9
09-218	Organic Chemistry II	9
09-207	Techniques in Quantitative Analysis	9
09-208	Techniques for Organic Synthesis and Analysis	9
Total Chemistry units		**56**

Psychology Courses		Units
85-102	Introduction to Psychology	9
85-219	Foundations of Brain and Behavior	9
85-xxx	Survey Psychology Courses *	18
85-310	Research Methods in Cognitive Psychology	9
or 85-300	Introduction to Research Methods	
or 85-314	Cognitive Neuroscience Research Methods	
or 85-320	Research Methods in Developmental Psychology	
or 85-330	Analytic Research Methods	
or 85-340	Research Methods in Social Psychology	
85-3xx	Advanced Psychology Electives	18
Total Psychology units		**63**

* Excluding 85-104 Psychopathology

Additional Advanced Elective 9 units

(Choose one of the following courses)

85-3xx	Advanced Psychology Elective	9
or		
03-3xx	Advanced Biology Elective	9

Additional Laboratory or Research Methods 9-12 units

(Choose one of the following courses)

03-344	Experimental Biochemistry	12
03-345	Experimental Cell and Developmental Biology	12
03-346	Experimental Neuroscience	12
85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9
85-320	Research Methods in Developmental Psychology	9
85-330	Analytic Research Methods	9
85-340	Research Methods in Social Psychology	9

Elective Units	Units
Free Electives	33-36
MCS Nontechnical Breadth or DC General Education requirements	36-48
Total Elective units	**69-84**

Minimum number of units required for degree: 360

B.A. Biological Sciences

The Department of Biological Sciences offers a Bachelor of Arts (B.A.) degree that is intended for students who wish to combine their interest in science with their interest(s) in other discipline(s) across campus. The requirements for the B.A. degree are distributed as follows:

Degree Requirements:

Biological Sciences		Units
03-151	Honors Modern Biology	10
or 03-121	Modern Biology	
03-201	Undergraduate Colloquium for Sophomores	2
03-220	Genetics	9
or 03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	
03-231	Honors Biochemistry	9
or 03-232	Biochemistry I	
03-320	Cell Biology	9
03-343	Experimental Techniques in Molecular Biology	9-12
or 03-124	Modern Biology Laboratory	

03-411	Topics in Research	1
03-412	Topics in Research	1
03-xxx	General Biology Electives [1]	18
03-3xx	Advanced Biology Electives [1]	18
Total Biology units		**86-89**

[1] Please see description and requirements for electives under the B.S. in Biological Sciences section of this Catalog.

Chemistry		Units
09-105	Introduction to Modern Chemistry I [2]	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-217	Organic Chemistry I	9
09-218	Organic Chemistry II	9
09-207	Techniques in Quantitative Analysis	9
Total Chemistry units		**47**

[2] Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

Mathematics, Physics, and Computer Science		Units
15-110	Principles of Computing	10
or 15-112	Fundamentals of Programming and Computer Science	
21-120	Differential and Integral Calculus	10
21-124	Calculus II for Biologists and Chemists	10
or 21-122	Integration and Approximation	
33-121	Physics I for Science Students	12
or 33-141	Physics I for Engineering Students	
33-122	Physics II for Biological Sciences & Chemistry Students	9
or 33-142	Physics II for Engineering and Physics Students	
99-101	Core@CMU	3
Total Science units		**54**

Elective courses	Units
MCS Nontechnical Breadth Requirements	72
Free Electives	96-99
Total Elective units	**168-171**

360Minimum number of units required for degree:

Additional Major and Dual Degree in Biological Sciences

Biological Sciences may be taken as an additional major (also known as a “double major”) or as a second degree, with another department granting the primary degree. The rules of the Biological Sciences Department for these two options are distinct, as discussed below.

Additional Major

In order to receive an Additional Major in Biological Sciences, with another department granting the primary degree, all requirements listed below must be fulfilled:

Biological Sciences		Units
03-151	Honors Modern Biology	10
or 03-121	Modern Biology	
03-201	Undergraduate Colloquium for Sophomores	2
03-220	Genetics	9
or 03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	
03-231	Honors Biochemistry	9
or 03-232	Biochemistry I	
02-250	Introduction to Computational Biology [1]	12
03-320	Cell Biology	9
03-343	Experimental Techniques in Molecular Biology	12
03-344	Experimental Biochemistry	12
or 03-345	Experimental Cell and Developmental Biology	
or 03-346	Experimental Neuroscience	
03-411	Topics in Research	1
03-412	Topics in Research	1
03-xxx	Biological Sciences Electives [2]	54
Total Biology units		**131**

[1]This course requires 15-110 or 15-112 as a prerequisite.

[2]Please see description and requirements for electives under the B.S. in Biological Sciences section of this Catalog.

Chemistry		Units
09-105	Introduction to Modern Chemistry I [3]	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-217	Organic Chemistry I	9
09-218	Organic Chemistry II	9
09-207	Techniques in Quantitative Analysis	9
09-208	Techniques for Organic Synthesis and Analysis	9
Total Chemistry units		**56**

[3] Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

Minimum number of units required for additional major: 187

Dual Degree

In order to receive a Dual Degree in another subject and Biological Sciences, all requirements of the Biological Sciences degree must be fulfilled. Students may choose to complete the B.A. or the B.S. in Biological Sciences, with or without Options. Students must complete all technical and non-technical requirements, and should consult with the Carnegie Mellon Biological Sciences advisor for questions about double counting. The number of units required for a Dual Degree is 90 more than the total units required by the department requiring the fewer total units. Since Biological Sciences requires 360 units, the lowest possible minimum for a Dual Degree with Biological Sciences is 450 units.

Minor in Biological Sciences

All university students are eligible to pursue a minor in biological sciences in conjunction with a major in any other department in the university. A minimum of six biological sciences courses (and two chemistry prerequisites) must be completed to fulfill the minor in biological sciences. The curriculum includes four required courses and two elective courses as specified below. Units awarded for undergraduate research are not applicable to elective courses. Courses taken in other departments or colleges will be considered on an individual basis by the Director of Undergraduate Studies.

Courses for the Minor in Biological Sciences

Prerequisites:		Units
09-105	Introduction to Modern Chemistry I	10
09-217	Organic Chemistry I	9

Required courses:		Units
03-121	Modern Biology	9
or 03-151	Honors Modern Biology	
03-220	Genetics	9
or 03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	
03-231	Honors Biochemistry	9
or 03-232	Biochemistry I	
03-320	Cell Biology	9
03-xxx	General Biology Elective [1]	9
03-3xx	Advanced Biology Elective [1]	9

[1]Please see description and requirements for electives under the B.S. in Biological Sciences section of this Catalog.

Minimum number of units required for the Minor in Biological Sciences: 73

Minor in Neuroscience

The curriculum within the Neuroscience minor will allow students from various disciplines to gain fundamental knowledge of neuroscience concepts. The interdisciplinary nature of the coursework echoes the nature of the field itself; students will select courses from the natural, social, and computer sciences. Neuroscientists not only require foundational knowledge of molecular, cellular, and systems neuroscience, but they should also understand the behavioral significance and appreciate how computational work and imaging techniques can aid in clarifying normal and abnormal functioning of these fundamental processes.

Students pursuing the minor in Neuroscience will:

- Acquire foundational knowledge of the basic biological foundations of the nervous system, from the cellular through systems levels.
- Understand the effects of basic neurological function on behavior, including cognition.
- Gain an appreciation of the interdisciplinary nature of the field of neuroscience.

All university students are eligible to pursue a minor in neuroscience in conjunction with a major in any other department in the university. A minimum of seven courses must be completed to fulfill the minor in neuroscience. The curriculum includes four required courses and three elective courses as specified below. Units awarded for undergraduate research are not applicable to elective courses. Courses taken in other departments or colleges will be considered on an individual basis by the Director of Undergraduate Studies.

NOTE: Because the curriculum within this minor may overlap with some degree requirements, no more than 2 courses fulfilling Neuroscience Minor requirements may count towards the requirements of a student’s major or other minor.

Course Requirements

Minimum units required for Neuroscience minor 63

Required courses (4):

		Units
03-121	Modern Biology	9
or 03-151	Honors Modern Biology	
03-362	Cellular Neuroscience	9
03-363	Systems Neuroscience	9
85-219	Foundations of Brain and Behavior	9
or 03-161	Molecules to Mind	

Neurobiology Elective Requirements:

27 units of electives required, including at least 1 course 300-level or higher

Neurobiology Electives		Units
03-133	Neurobiology of Disease	9
03-351	Computation and Biology Integrated Research Lab	9
03-360/02-319	Genomics and Epigenetics of the Brain	9
03-365	Neural Correlates of Learning and Memory	9
03-366	Neuropharmacology: Drugs, Brain and Behavior	9
85-104	Psychopathology	9
85-211	Cognitive Psychology [1]	9
85-310	Research Methods in Cognitive Psychology	9
85-370	Perception	9
85-406	Autism: Psychological and Neuroscience Perspectives	9
85-414	Cognitive Neuropsychology	9
85-435	Biologically Intelligent Exploration	9
03-119	Biology for Life Special Topics Micro *Offered only in Doha, requires approval from minor advisor	3

[1]NOTE: 85-213 may be used instead of 85-211 when offered

Masters Degrees

Students who are interested in more advanced training in the intersection of biology and computation or biology and engineering may want to consider the Department of Biological Science's Masters programs: the Master of Science in Quantitative Biology and Bioinformatics (https://www.cmu.edu/bio/graduate/ms_quant_bioinformatics/), the Master of Science in Computational Biology (https://www.cmu.edu/ms-compbio/) (joint with the Department of Computational Biology), or the Master of Science in Biotechnology and Pharmaceutical Engineering (https://www.cmu.edu/ms-biotech-pharma/) (joint with the Department of Chemical Engineering).

For more information about these programs, contact the Biological Sciences Graduate Programs Office (bio-graduate-office@andrew.cmu.edu).

Honors Program in Research Biology

The departmental Honors Program offers an opportunity to become extensively involved in research. The program requires students to conduct an independent project and to prepare a formal thesis that is written and defended in the senior year. This program does not preclude a student from completing any of the options within the department nor is it the only way in which students can participate in undergraduate research, although it is excellent preparation for graduate studies. Please contact the Director of Undergraduate Studies for more information.

Transfer Credit for Biological Sciences Courses

1. Requests for transfer credit for biology classes taken at other institutions should be made to the Director of Undergraduate Studies. Students making such requests should follow the policies and procedures in place within their home colleges in assembling materials for such requests. Consult with your advisor on the appropriate steps.
2. Requests should be placed **before** paying tuition for a class in case transfer credit is denied. Allow 1-2 weeks for approval.
3. At minimum requests must be accompanied by a complete syllabus including the textbook that will be used, a detailed list of topic areas and an indication of whether or not the course is part of the curriculum for science majors at the other institution. Check to ensure that the institution is on a semester system. Most schools on a quarter system (many in the UC system of schools) teach general biology over three quarters; therefore one of these classes would not be equivalent to one CMU class.
4. In assessing the suitability of courses for transfer credit, the following factors are considered:
    - The rigor of the course must be comparable to that offered at Carnegie Mellon. This is usually assessed via the quality of the institution and its biology program, the textbook used, the amount of time spent on topic areas, and the course assessment structure.
    - The topic areas should match to a degree of at least 80% those covered in the comparable course at Carnegie Mellon University.
5. No transfer credit will be awarded for the laboratory classes required for the biological sciences majors at Carnegie Mellon University, 03-124, 03-343, 03-344, 03-345 and 03-346. Core biological sciences courses required for the BS degrees and the additional major that are numbered 03-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances. Transfer credit for biological elective coursework will be assessed on a case by case basis by the Director of Undergraduate Studies.
6. Students wishing to transfer credit for 03-121 Modern Biology from another institution must meet the following requirements:
    - The course in question should have at least an 80% match in topics with 03-121. Topics in 03-121 cover the genetic, molecular, cellular, developmental, and evolutionary mechanisms that underlie biological processes and include: Cell theory; Cell chemistry; Cell structure; Function and structure of proteins, DNA, RNA, lipids and carbohydrates; Cell respiration and fermentation; The cell cycle; Cell-cell interactions and communication; Transcription; Translation; RNA processing in Eukaryotes; DNA replication; DNA mutation and repair; Meiosis; Mitosis; and Regulation of Gene Expression. *This information is sometimes available in the course description, but more detail is often found in a course syllabus.*
    - The textbook used in the transfer course should be at a comparable level to S. Freeman et al (2016) "Biological Science" Sixth Edition, Pearson, ISBN 9780134255033 (eText).
    - Introductory level courses that focus on other biology areas (i.e. anatomy, physiology, ecology, evolution, and/or development) will not be accepted for 03-121 credit. These courses may receive credit for a general biology elective.

Faculty

NESRINE AFFARA, Associate Teaching Professor, Carnegie Mellon-Qatar – Ph.D., The Ohio State University; Carnegie Mellon, 2017–

CATHERINE ARMBRUSTER, Assistant Professor – Ph.D. , University of Washington; Carnegie Mellon, 2024–

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JAMES F. WILLIAMS, Professor Emeritus – Ph.D., University of Toronto; Carnegie Mellon, 1976–

C. ROY WORTHINGTON, Professor Emeritus – Ph.D., Adelaide University; Carnegie Mellon, 1969–

Department of Biological Sciences Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

03-050 Study Abroad

Fall
This course number is a placeholder for biological sciences majors who are studying abroad.

03-051 Study Abroad

Spring
This course number is a placeholder for biological sciences majors who are studying abroad.

03-052 Summer Internship

Summer: 3 units
Course Description: The Department of Biological Sciences considers experiential learning opportunities important educational options for its undergraduate students. One such option is an internship, normally completed during the summer. Students do not need to officially register for an internship unless they want it listed on their official transcripts. The Director of Undergraduate Programs (or designee) will add the course to the student's schedule, and the student will be assessed tuition for 3 units. Upon completion of the internship, students must submit a 1-2 page report of their work experience to the Director of Undergraduate Programs (or other designated faculty member). After the reports have been reviewed and approved, a "P" grade will be assigned.

03-113 Biologies in Text and Film

All Semesters: 9 units
The course enables students to interpret and apply scientific findings meaningfully by enhancing their critical thinking and analytical skills through the examination of how science is represented in media. In their personal lives, students become more discerning consumers of scientific information. learning to differentiate between accurate scientific facts and speculative fiction. Professionally, the course equips students with the ability to communicate complex scientific concepts to diverse audiences and to apply scientific reasoning to problem-solving in various fields. Civically, the course fosters an understanding of the societal and ethical implications of scientific advancements, empowering students to engage in informed public discussions to make thoughtful decisions on science-related issues.

03-116 Phage Genomics Research

Spring: 6 units
Spring Semester: The DNA sequences will be analyzed with bioinformatic tools and compared with those of phages isolated at other locations to identify genes, their organization, the differences that may characterize different phage groups, and how these have arisen during evolution.
Prerequisite: 03-115

03-117 Frontiers, Analysis, and Discovery in Biological Sciences

Fall and Spring: 6 units
In this hands-on laboratory class, students will investigate a current biology problem. Students will read literature articles, design hypotheses, plan and carry out experiments, analyze and interpret data, and design future questions as part of a collaborative research team. In addition, teams will work with faculty and fellow students to understand and explore the relevance of their projects in the field of biology and other disciplines. Finally, teams will communicate results in an oral presentation to peers and faculty. Students will gain research skills, analytical skills, communication skills (both written and oral), and project design skills.
Prerequisites: 03-110 or 03-121 or 03-151

03-118 Beer: A Yeast's Perspective

Fall and Spring: 6 units
This is a combined lecture and laboratory course in which students will investigate the biochemistry of fermentation using strains of yeast commonly used in brewing science. Lectures and readings will cover all necessary information to succeed in the course, including topics like yeast metabolism, fermentation at the micro and industrial levels, and a history of fermentation's influence on society. Lab experiments will investigate yeast growth and fermentation processes in various strains used in brewing, and quantitative assessments of beer at the molecular level. The course puts a focus on microbiology lab techniques and yeast biochemistry; however, no previous lab experience or biology coursework is required, and anyone with an interest in the science behind brewing yeast can succeed in the class.

03-119 Biology for Life Special Topics Micro

Intermittent: 3 units
Special Topics in Biological Sciences Micro Courses. Topics will vary depending on the semester and instructor. Courses offered under this course number will not require prior knowledge of or exposure to biological sciences and are open to students from any major and class year. Please read individual section descriptions for more information. Spring 2023: Sections W3 and amp; A4: Stayin' Alive: Human Immunity: This course will provide the tools for the layperson to understand how their immune system works to prevent disease and cancer. The course also explains the basis of modern immunotherapies such as vaccines and cancer treatment. Biology at the high-school level is the only requirement. This requirement can be waived after completing a short series of simple on-line modules.

03-120 Biology for Life Special Topics Mini

Fall and Spring: 6 units
Special Topics in Biological Sciences Mini Courses. Topics will vary depending on the semester and instructor. Courses offered under this course number will not require prior knowledge of or exposure to biological sciences and are open to students from any major and class year. Please read individual section descriptions for more information. Fall 2024 Section A2: Sex, Race, and amp; Science: Humans make sense of the world through categorization. We have created the categories of race and sex, among others, to understand our own diversity. But how much do we know about whether these divisions are scientifically valid? How much variation exists within and even outside of them? To what extent do these categories help us make important discoveries in basic research and medicine, and to what extent do their assumptions and blindspots hold us back? In this class, we will read a mix of research papers, popular science communication, and feminist theory to explore these questions. The majority of each class will be spent in discussion, and the main assessments will be reading reflections, quizzes, and an independent project. No prerequisite knowledge is required. Section W1: Neurobiology of Disease: This introductory-level mini course explores the biological basis of neuropsychiatric diseases and their treatments. It is intended to broaden students' understanding of how these diseases are diagnosed, treated, and studied. It will explore the anatomical and biological basis of several neuropsychiatric diseases (including OCD, ADHD, mood disorders, and anxiety), with emphasis placed on the cellular and anatomical basis of the diseases as well as methods of treatment. We will discuss neurobiological research to serve as a basis for better understanding mechanisms of disease and investigating new avenues for treatment. No prerequisite knowledge is required.

Course Website: https://www.cmu.edu/bio/undergrad/academics/intro_courses.html

03-121 Modern Biology

All Semesters: 9 units
This is an introductory course that provides the basis for further studies in biochemistry, cell biology, genetics and molecular biology. This course emphasizes the chemical principles underlying biological processes and cell structures as well as the analysis of genetics and heredity from a molecular perspective. This is the introductory biology course for all science and non-science majors.

Course Website: http://www.cmu.edu/bio/undergrad/courses/index.html (http://www.cmu.edu/bio/undergrad/courses/)

03-124 Modern Biology Laboratory

Fall and Spring: 9 units
This laboratory is designed to introduce students to modern concepts in the biological sciences. The experiments illustrate many of the principles covered in 03-121 and 03-230. Experimentation using living organisms and/or their tissues, cells or molecules is an essential component of this course.

03-125 Evolution

Fall: 9 units
Evolutionary theory is the unifying principle of biology. A good comprehension of the concepts that underlie this theory is therefore important to properly appreciate and understand any biological process. This course is designed for students intending to continue studies in biology so that they may gain an understanding of the evolutionary framework in their more advanced courses, and also non-biology majors who want to extend their knowledge of biology at an introductory level. The lectures will include (i) an examination of the history and development of evolutionary theory, (ii) consideration of some of the facts that have established the theory, (iii) an introduction to the concepts of phylogenetics, (iv) discussion of the patterns and mechanism that lead to the diversity and origins of the groups of life, (v) an introduction to genetics and population genetic theory, and (vi) discussion of and how this applies to natural selection and speciation. The course will also include some more specialist topics, including evolution of development, sexual selection, evolutionary applications to medicine and conservation biology, and genome evolution. Assessment will be based on several in-class exams and quizzes, homework assignments, a written term paper, and a final exam.

03-128 Biology for Life Special Topics

Fall and Spring: 9 units
Special Topics in Biological Sciences. Topics will vary depending on the semester and instructor. Courses offered under this course number will not require prior knowledge of or exposure to biological sciences and are open to students from any major and class year. Please read individual section descriptions for more information. Summer 1/All 2023: Tropical Ecology at Monteverde Institute. This is a course offered through a study abroad program to Costa Rica. Students will be addressing general questions about tropical ecosystems such as: What are tropical forests? What makes them different than other forests? Where are they and why do global climate patterns result in their geographic distribution? What are the different kinds of tropical forests? What controls the diversity, phenology and successional processes of tropical forests? What are tropical marine ecosystems? This course will also cover specific ecological interactions between organisms such as: seed dispersal, pollination, herbivory, mutualisms, prey-predator interactions in the tropics. Students will also learn about humans in the tropics, both those groups that have evolved and adapted to these environments and the current threats imposed by local/global economic systems. As a part of this course, students will participate in field work and use nature as a laboratory to study the diversity of life forms and interactions between plants, animals, and microorganisms and with the physical environment.

Course Website: https://www.cmu.edu/bio/undergrad/academics/intro_courses.html

03-129 Human Health and Disease

Intermittent: 9 units
The main objective of the course is not only to teach the students how the body works but also to construct a global view of all 9 organ systems and how these organ systems coordinate with each other when homeostasis is challenged. An additional emphasis of this course is the pathophysiological changes that can be associated with each organ malfunction.

03-132 Basic Science to Modern Medicine

Fall and Summer: 9 units
The goal of this course is to give students an understanding of the biology that impacts their everyday lives. Disease can be a tragic part of human life, a fact that is even more apparent in during a global pandemic. To understand how specific diseases like COVID-19 or cancer affect the human body, and how modern medicine can tackle them, this course includes a fundamental study of the basic molecular biology, genetics, and cell biology that underlies disease. This is a topics-based course, with topics chosen to cover aspects of biology and health that students are likely to encounter in their daily lives. The topics for summer 2024 will include COVID-19, genome editing, and cancer. We will explore these topics from both a basic science and a modern medicine perspective. Student's will gain the expertise to critically evaluate media reports about biology and health, and to ask the questions that will help them to make educated decisions in their lives.

Course Website: http://www.cmu.edu/bio/undergrad/courses/index.html (http://www.cmu.edu/bio/undergrad/courses/)

03-133 Neurobiology of Disease

Spring: 9 units
This course will explore the biological basis of several neurological and neuropsychiatric diseases, with an emphasis on medical diagnostic tools and techniques. It will include discussions of the anatomical basis of neurological diseases as well as recent research into understanding the mechanisms of disease. This course is intended to broaden students' understanding of how diseases are diagnosed and studied. Students will also learn how basic neurological and psychiatric evaluations are conducted. We will discuss neurobiological research to serve as a basis for understanding brain structures and functional alterations in a variety of developmental, degenerative, neurological, and psychiatric disorders.

Course Website: http://www.cmu.edu/bio/undergrad/courses/index.html (http://www.cmu.edu/bio/undergrad/courses/)

03-135 Structure and Function of the Human Body

Fall: 9 units
Structure and Function of the Human Body is a non-majors course designed to explore fundamental relationships between form and function of the human body. The anatomy and physiology of major organ systems will be studied in the context of normal and disease states. Students will learn about critical biological processes such as the central dogma, membrane diffusion and transport, cell signaling, gas exchange, blood flow, nutrient absorption, blood pH balance, and action potential generation and propagation. Students will then apply this knowledge to understand how organs respond to various inputs in maintaining homeostasis. Hands-on demonstrations will be incorporated to provide a practical framework for the information presented in lectures. At the culmination of the semester, students will gain a broad understanding of how the body systems function at the cellular, tissue and organ levels and be able to relate simple physiological processes to better understand highly prevalent diseases in society.

03-140 Ecology and Environmental Science

Fall: 9 units
Environmental science is a highly interdisciplinary field that integrates knowledge and modes of inquiry from across the sciences to understand some of the most important challenges of the 21st century. This course provides a foundational background in scientific method, critical thinking and problem solving strategies used to study and evaluate the environment. Modules include: principles of ecology and eco-systems, biological diversity, biogeochemical cycles, endangered species management, human population growth, atmosphere, climate and global warming. Assessment will include class attendance, quizzes, individual and small group projects, in class exams. Projects may involve visits to local sites.

03-151 Honors Modern Biology

Fall: 10 units
Honors Modern Biology (03-151) is an honors introductory course. This course has been designed for freshman students with an interest in a major in the biological sciences who have had solid preparation in this field as indicated by the following examinations: SAT II Molecular Biology, AP, or IB Biology. This course will present the concepts and principles necessary for a general understanding of the processes occurring in living cells and is the basis for further study in cell biology, biochemistry, genetics, molecular and developmental biology. While similar core topics will be covered in all sections of Modern Biology, this section will be offered at an accelerated pace, requiring more independent learning. The extra class time this pacing provides will allow the exploration of the molecular basis of life to help students integrate and apply the core principles of biology covered in the course. THIS SECTION IS RESERVED FOR INCOMING FIRST-YEAR MCS STUDENTS.

Course Website: http://www.cmu.edu/bio/undergrad/courses/index.html (http://www.cmu.edu/bio/undergrad/courses/)

03-161 Molecules to Mind

Spring: 9 units
This course provides a depth-first approach to understanding neuroscience. We will begin with a clinical focus on neuroanatomy, introducing students to some basic neurological diagnostic techniques. We will then explore the biological basis of neuronal function and link the function of individual neurons to a broader context of neural systems. This will be done in the context of primary literature. Students who complete this course will therefore have an understanding of research methods and be prepared to evaluate scientific literature. The course will have a strong focus on the biological and cellular basis of neuronal excitability and also give students significant, in depth exposure to the function of synapses and their plasticity. Finally, the course will give students an in depth look at sensory and/or motor systems by focusing on one system in particular.

03-201 Undergraduate Colloquium for Sophomores

Fall
The purpose of this seminar series is to update biology undergraduates about university and departmental functions, seminars, etc. that are pertinent or useful. In addition, research talks by faculty and undergraduates will be used to introduce students to the research being conducted in faculty laboratories. Additional topics may include graduate and medical school applications, career options, topics in the press, and important scientific discoveries.

03-202 Undergraduate Colloquium for Sophomores

Spring
Missing Course Description - please contact the teaching department.

03-206 Biomedical Engineering Laboratory

Fall and Spring: 9 units
This laboratory course is designed to provide students with the ability to make measurements on and interpret data from living systems. The experimental modules reinforce concepts from 42-101 Introduction to Biomedical Engineering and expose students to four areas of biomedical engineering: biomedical signal and image processing, biomaterials, biomechanics, and cellular and molecular biotechnology. Several cross-cutting modules are included as well. The course includes weekly lectures to complement the experimental component. Priority for enrollment will be given to students who have declared the Additional Major in Biomedical Engineering. Notes: This course number is reserved for students who are CIT majors and registered with the HPP program. If you require a biology lab for pre-health admissions requirements, register for 42-203 and Dr. Sang Chalacheva will work with students once the semester begins to register for 03-206 instead of 42-203. Priority for enrollment will be given to students who have declared the Additional Major in Biomedical Engineering.
Prerequisites: (03-121 or 03-151) and 42-101

03-210 Independent Study

Fall and Spring
Students will read papers from the original literature under the direction of a faculty member. Students will be required to demonstrate mastery of the readings by discussions with the sponsoring faculty member, oral presentations, or writing of one or more papers summarizing and extending the information in the readings. If appropriate, students may write a program(s) to satisfy this last requirement. A student may take this course only once. This is a mini format course. Special permission required. **Students MUST contact bio-ungrad@andrew.cmu.edu and complete the application form in order to participate and amp; register.**

03-220 Genetics

Fall: 9 units
The mechanisms of transmission of inherited traits in viruses, bacteria, fungi, plants and animals are discussed. Molecular mechanisms of gene expression and gene regulation are analyzed. Recombinant DNA and its applications in genetic analysis, biotechnology, forensics, agriculture, medicine, and the pharmaceutical industry are presented. Special topics in human genetics are considered, such as the genetics of cancer. Principles and methods for the study of developmental genetics, population genetics and complex traits are also introduced.
Prerequisites: 03-151 or 03-121

03-221 Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis

Spring: 9 units
Scientific and technical advances in genetics have accelerated dramatically since the draft human genome sequence was published in 2001. The development of massively parallel DNA sequencing and associated technologies has transformed the way we approach genetic questions. Contemporary genetics is increasingly concerned with generating, processing and analyzing vast amounts of data to extract information about genetic variation, expression, interactions and associations. At the same time, comparative genomics, bioinformatic and reverse genetic methods are transforming the way in which gene functions are investigated, while the development of powerful methods for precise modification of genomes is opening the way to cell- and gene-based therapies for disease. In parallel, the promise of precision or personalized medicine is predicated on advances in understanding of complex traits, genetic interactions and networks. These and other topics will be covered following a review of basic principles of gene structure and expression, the fundamental principles of Mendelian genetics, and their underpinnings in cellular mechanisms for the replication, recombination and transmission of genetic material. Although the topics overlap extensively with 03220 (Genetics), they will be presented at a more advanced level, with a greater emphasis on current methods of quantitative and statistical analysis. This course is recommended for students with a particular interest in emerging technologies for analysis of human genetics, genomics, gene therapy and precision medicine.
Prerequisites: (03-121 Min. grade B or 03-151 Min. grade B) and (21-124 Min. grade C or 36-217 Min. grade C or 36-200 Min. grade C or 36-225 Min. grade C or 15-259 Min. grade C or 36-219 Min. grade C or 36-218 Min. grade C or 36-201 Min. grade C or 36-247 Min. grade C or 15-359 Min. grade C)

03-230 Intro to Mammalian Physiology

Spring: 9 units
This course has been designed to explore human physiology at an introductory level. Emphasis will be placed on the physiological processes in an organ system framework and focus on a wide range of pertinent clinical topics. Our aim is to instill in you a deeper appreciation for the complexity and beauty of the human body, and most importantly, to motivate you to carry away physiological principles that you may need later in your profession or simply may be relevant to a real-world situation.
Prerequisites: 03-151 or 03-121

03-231 Honors Biochemistry

Spring: 9 units
This course provides an introduction to molecules and processes found in living systems. Amino acids, sugars, lipids and nucleotides and their corresponding higher structures, proteins, polysaccharides, membranes and nucleic acids are studied. Kinetics and mechanisms of enzymes as well as elementary metabolic cycles and the energetics of biological systems are studied with a quantitative approach.
Prerequisites: 03-121 or 03-151

03-232 Biochemistry I

Spring: 9 units
This course provides an introduction to the application of biochemistry to biotechnology. The functional properties of amino acids, nucleotides, lipids, and sugars are presented. This is followed by a discussion of the structural and thermodynamic aspects of the organization of these molecules into higher-order structures, such as proteins, nucleic acids, and membranes. The kinetics and thermodynamics of protein-ligand interactions are discussed for non-cooperative, cooperative, and allosteric binding events. The use of mechanistic and kinetic information in enzyme characterization and drug discovery are discussed. Topics pertinent to biotechnology include: antibody production and use, energy production in biochemical systems, expression of recombinant proteins, and methods of protein purification and characterization. The course is an alternate to 03-231.
Prerequisites: 09-107 or 09-105 or 06-221 or 06-223

03-320 Cell Biology

Fall: 9 units
This course provides descriptive information and mechanistic detail concerning key cellular processes in six areas: membrane function, protein targeting, signaling, cytoskeleton, cell division, and cell interaction. An attempt is made to introduce the methodology that was used to obtain this information and to discuss how our understanding of these processes relates to the treatment of human disease.
Prerequisites: (03-120 or 03-121 or 03-151) and (03-233 or 03-232 or 03-231)

Course Website: http://www.cmu.edu/bio/undergrad/courses/index.html (http://www.cmu.edu/bio/undergrad/courses/)

03-327 Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method

Intermittent: 9 units
An advanced introduction to the evolutionary concepts and bioinformatic skills that are central to molecular, cell, developmental, and microbiology. Proteins that share common ancestry also share functional properties. This is the guiding principle of model organism research and sequence-based bioinformatics. Evolutionary trees (phylogenies) and multiple sequence alignments provide evidence for predicting structural and functional constraints, sites of molecular interaction, and residues that confer functional specificity. In 2021, phylogenetics is emerging as an essential technique in metagenomics, cancer, and infectious disease, driven by technological advances such as high through-put sequencing and single-cell phenotyping. This course covers both the conceptual foundation and the practical skills of evolutionary bioinformatics. Students will acquire the "tree thinking" skills required for critical interpretation of phylogenetic analyses and figures in the literature and a rigorous understanding of phylogenetic inference methods. Theoretical knowledge will be complemented by hands-on experience with sequence data repositories, bioinformatic tools for database retrieval, sequence analysis, and tree building. Students will walk out of the course with the knowledge required to apply those tools correctly to messy, genuine data sets, and the ability to evaluate alternate hypotheses in light of these bioinformatic analyses. Students with a range of computational backgrounds are welcome.
Prerequisites: 03-121 or 03-151

Course Website: http://www.cs.cmu.edu/~durand/Phylogenetics/

03-342 Introduction to Biological Laboratory Practices

Fall: 1 unit
This course is designed for students in the BSA degree program. It is designed to be an introduction to basic laboratory practices. The course will introduce biological and chemical safety training and basic laboratory practices. Techniques of solution preparation and titration, pipetting, UV/VIS spectroscopy, and quantitation of biological compounds will be covered.

03-343 Experimental Techniques in Molecular Biology

Fall: 12 units
This laboratory course is designed to teach experimental methods of modern biology. Experiments in microbial genetics, molecular biology and eukaryotic genetics are performed. Emphasis is placed on understanding and applying the biological principles of each experiment. This course is designed to be taken during the junior year and is intended to prepare students for undergraduate research. Experimentation using living organisms and/or their tissues, cells or molecules is an essential component of this course.
Prerequisites: (03-231 or 03-232) and (qc211 or 09-223 or 09-208 or 09-222)

Course Website: http://www.cmu.edu/bio/undergrad/courses/index.html (http://www.cmu.edu/bio/undergrad/courses/)

03-344 Experimental Biochemistry

Spring: 12 units
This course is designed to be taken as a sequel to 03-343. Experiments cover a variety of methods for investigating the structure and function of biological molecules. Experimental methods with proteins, enzyme kinetics, lipids, spectroscopy, and isolation and quantization of biological molecules are covered. During several experiments, students design their own projects. Experimentation using living organisms and/or their tissues, cells or molecules is an essential component of this course.
Prerequisites: 03-343 and (03-231 or 03-232)

03-345 Experimental Cell and Developmental Biology

Spring: 12 units
This laboratory is designed to teach concepts and experimental methods in cell and developmental biology. Students work with a variety of organisms to examine how cells traverse development from rapidly dividing, undifferentiated cells, through cell commitment and the establishment of spatial and temporal patterns of gene expression, to the specific characteristics and responses of terminally differentiated cells. The course makes extensive use of video microscopy with phase contrast, DIC and fluorescence microscopes. Biochemical, immunological and molecular biological techniques are used to probe the molecules and processes of cells undergoing development. Experimentation using living organisms and/or their tissues, cells or molecules is an essential component of this course.
Prerequisites: 03-343 and (03-232 or 03-231) and (03-240 or 03-320)

03-346 Experimental Neuroscience

Intermittent: 12 units
This laboratory is designed to teach concepts and experimental methods in neurobiology. Students work with a variety of organisms to study the anatomy, function, and development of the nervous system. Immunological, molecular, biochemical, and ballistic labeling techniques are used to examine the gene expression and structure in the mature and developing nervous system. Students study the function of neurons through neurophysiological techniques in invertebrates and computer simulation. This course makes extensive use of video microscopy and phase contrast, DIC, and fluorescence microscopes.
Prerequisites: (03-240 or 03-320) and 03-362 and 03-343

03-350 Developmental Biology

Spring: 9 units
How does a complex, multicellular organism arise from a single cell? How do cells with identical genomes acquire distinctive properties? What are the medical consequences of abnormal embryonic development? How does regeneration occur? How has evolution modified developmental programs to produce different body plans? These are some of the central questions in the field of developmental biology. This course serves as an introduction to current concepts and experimental approaches in this rapidly advancing field. Topics in the course include genomics, differential gene expression, cell signaling, cell movements, tissue morphogenesis, stem cells, human development, and regeneration. The course examines the genes and signaling pathways that control development and the role that mis-regulation of these pathways plays in human disease.
Prerequisites: 03-320 or 03-240

03-351 Computation and Biology Integrated Research Lab

Fall: 9 units
Modern biological research is heavily interdisciplinary in nature requiring the use of a diverse set of experimental techniques and computational analysis. This course provides students with a modern research experience while training them to communicate and collaborate in an interdisciplinary setting to better prepare them to join the workforce as members of interdisciplinary teams. This will be accomplished by focusing efforts on a real research problem requiring sophisticated experimentation and computation for success. Class time will include both laboratory research time (wet lab and computational) and activities designed to teach and practice communication methods for interdisciplinary teams. Students are expected to have a strong background in biology or computation and an interest in both.
Prerequisites: 03-124 or 03-117 or 03-343 or 15-112

03-360 Genomics and Epigenetics of the Brain

Fall: 9 units
This course will provide an introduction to genomics, epigenetics, and their application to problems in neuroscience. The rapid advances in genomic technology are in the process of revolutionizing how we conduct molecular biology research. These new techniques have given us an appreciation for the role that epigenetics modifications of the genome play in gene regulation, development, and inheritance. In this course, we will cover the biological basis of genomics and epigenetics, the basic computational tools to analyze genomic data, and the application of those tools to neuroscience. Through programming assignments and reading primary literature, the material will also serve to demonstrate important concepts in neuroscience, including the diversity of neural cell types, neural plasticity, the role that epigenetics plays in behavior, and how the brain is influenced by neurological and psychiatric disorders. Although the course focuses on neuroscience, the material is accessible and applicable to a wide range of topics in biology.
Prerequisites: 03-220 or 03-330 or 03-221

03-362 Cellular Neuroscience

Fall: 9 units
Modern neuroscience is an interdisciplinary field that seeks to understand the function of the brain and nervous system. This course provides a comprehensive survey of cellular and molecular neuroscience ranging from molecules to simple neural circuits. Topics covered will include the properties of biological membranes, the electrical properties of neurons, neural communication and synaptic transmission, mechanisms of brain plasticity and the analysis of simple neural circuits. In addition to providing information the lectures will describe how discoveries were made and will develop students' abilities to design experiments and interpret data.
Prerequisites: 42-202 or 03-161 or 03-320 or 03-230 or 85-219

03-363 Systems Neuroscience

Spring: 9 units
Modern neuroscience is an interdisciplinary field that seeks to understand the function of the brain and nervous system. This course provides a comprehensive survey of systems neuroscience, a rapidly growing scientific field that seeks to link the structure and function of brain circuitry to perception and behavior. This course will explore brain systems through a combination of classical, Nobel prize-winning data and cutting edge primary literature. Topics will include sensory systems, motor function, animal behavior and human behavior in health and disease. Lectures will provide fundamental information as well as a detailed understanding of experimental designs that enabled discoveries. Finally, students will learn to interpret and critique the diverse and multimodal data that drives systems neuroscience.
Prerequisites: 03-240 or 42-202 or 85-219 or 03-320 or 03-161 or 03-230

03-365 Neural Correlates of Learning and Memory

Spring: 9 units
This course will examine the biological substrates of learning, memory, and behavioral adaptation. The focus will be on addressing how neural circuits change during new skill acquisition and adapt to variations in the environment. An introduction to experience-dependent changes in neural structure and function, in addition to behavioral learning paradigms, will be provided. Then we will consider the ways in which specific changes in biological substrates give rise to the emergent properties that drive behavioral adaptation, followed by in depth coverage of deciphering which biological substrates constitute a lasting memory trace. Finally, the concept of age-dependent learning will be examined. Concepts and specific examples will come through reading of primary literature and selected readings from advanced texts.
Prerequisites: 03-320 or 03-161 or 85-219 or 03-240

03-366 Neuropharmacology: Drugs, Brain and Behavior

Fall: 9 units
This course is designed to give students a comprehensive understanding of the major neurotransmitter systems in the brain. Students will explore approaches to understanding how various neurotransmitters function in sensory and motor systems as well as how they are modulated by endogenous and exogenous agents. The exploration will include basic principles of neural communication, signal transduction and second messenger systems, main classes of neurotransmitters, and the effects of medications and drugs of abuse. In terms of sensory and motor systems, student will learn how different neurotransmitters affect different aspects of systems neuroscience and how a single neurotransmitter can have multiple roles in different systems. Students will learn how these processes affect the endocrine system, neuroinflammatory responses, addictive behaviors, and neurotoxic or degenerative conditions.
Prerequisites: 03-232 or 03-362 or 03-231 or 03-133

Course Website: http://www.cmu.edu/bio/undergrad/courses/index.html (http://www.cmu.edu/bio/undergrad/courses/)

03-380 Virology

Fall: 9 units
The concepts and methods of virology are covered, with emphasis on animal viruses, within the framework of cell biology, genetics, molecular biology, immunology, pathology, and epidemiology. The strategies that a wide variety of different DNA and RNA viruses, including some new and emerging ones, use to replicate and express their genomes during infection of host cells will be examined in some detail. The effects that viruses inflict on these cells will also be examined, as will some of the host cell responses generated by such virus-cell interactions, including interferon induction, the antiviral response generated by interferon, and oncogenic transformation. In addition, anoverview of procedures used for prevention and treatment of viral diseases via vaccinesand antiviral drugs, respectively, will be presented, as will a brief discussion of viroids and prions, and the characteristics of these agents which distinguish them from viruses.
Prerequisites: 03-240 or 03-320

03-390 Molecular and Cellular Immunology

Spring: 9 units
This is a course that covers the fundamentals of cellular and molecular immunology in a comprehensive manner. The objective of this course is to introduce the students to the immune system, the cells that constitute it, their ontogeny, their structure, activities and responses to stimuli and the systems/signals that integrate these cells into a coherent functional entity. Additionally, the course will demonstrate where, when, and how, the immune system responds in pathologic states, how its cells can themselves become the causes of pathologies, and how medical science targets and uses the immune system to prevent and treat a wide range of diseases.
Prerequisites: (03-231 or 03-232) and (03-320 or 03-240)

03-391 Microbiology

Spring: 9 units
The course provides introductory level microbial science and molecular biology that is aimed for students from all disciplines of natural science. It covers microbiology, genetics, genomics, as well as bacterial, fungal, and protozoan pathogenesis. Topics include: the human microbiome, genome sequencing, gene transfer across species, virulence, and drug resistance.
Prerequisites: 03-232 or 03-231

03-409 Applied Cell Biology

Intermittent: 3 units
The course provides a hands-on experience in biology lab to conduct experiments, collect and analyze scientific data with the purpose of using the data to infer biological principals. Students will learn the details of western blot technique, commonly used in biology labs. In addition, they will apply the technique to study how insulin triggers specific signaling in target cells. This lab module will reinforce the students' understanding of material seen in Cell Biology lecture course (co-requisite 03-240) and will prepare them for future lab courses.

03-410 Special Topics in Biological Sciences

Fall and Spring: 9 units
Special Topics in Biological Sciences. Topics will vary depending on the semester and instructor. Please read the individual section descriptions for more information.
Prerequisites: 03-232 or 03-231

03-411 Topics in Research

Fall
During the year students attend weekly seminars given by outside speakers or members of the Biology Department on current research topics in modern biology; some seminars outside of the department may be substituted.

03-412 Topics in Research

Spring
Students attend weekly seminars by scientists from other universities who have been invited by the Department of Biological Sciences to present their research to our faculty, postdoctoral scientists, graduate students, and staff. A written response to questions about the seminar is prepared by each student during the seminar and turned in to the instructor at the end of the seminar.

03-435 Cancer Biology

Fall: 9 units
Cancer affects roughly 1 in 3 people worldwide, and originates from both hereditary as well as environmental causes. Its prevalence makes it practically inescapable. Its of great relevance from both scientific and sociocultural perspectives. This course aims to examine various hallmarks of the biology of cancer while exploring novel concepts that challenge our understanding of cell biology. From the perspective of a cancer cell, we will learn about basic concepts of cell division, DNA replication, cell signaling, cell cycle control, cell metabolism, the regulation of gene expression in human cells, oncogenes, tumor suppressor genes, mutations, the process of metastasis, cancer diagnosis, cancer treatments and ethical questions surrounding treating patients, the epidemiology of cancer including prevalence and historical trends in diagnosis, as well as social impacts of a cancer diagnosis. Students will also explore the primary literature and scientific review articles to better understand research and methods of investigation into the cellular and molecular processes of tumorigenesis. This course will include interactive lectures, guest speakers, and in class discussion exercises aimed at building class participation and association, as well as confidence in public speaking about the sciences. Given the well-documented link between stress and cancer, there will also be a small component aimed at making students aware of health and wellness, such as reducing stress and anxiety.
Prerequisites: 03-220 or 03-221 or 03-330

03-439 Introduction to Biophysics

Fall: 10 units
Biological physics, or the physics of living systems, is an exciting interdisciplinary frontier of physics that aims to understand the phenomenon of life using concepts and tools from Physics. This intermediate level course will introduce the general concepts and principles underpinning the physical behavior of living systems, from the dynamics of proteins and molecules to collective behavior of living cells and organisms. The course will develop key physics concepts that are most vital to biological processes, including energy conversion, information transfer, mechanics of movement, statistical phenomena, and fluid flow. We will apply these physics concepts to demonstrate how biological systems function, build simplified mathematical models to predict behavior, and use experimental data to inform and test models. The integration of biological phenomena, physical concepts, mathematical modeling, and analysis of experimental data represents an entirely new mode of learning, based on strategies adopted in research. These strategies will break traditional disciplinary barriers between physics and biology. The students will be expected to gain an intuitive grasp of ways to: frame the physical problem, identify appropriate theoretical frameworks, analyze experimental data, and ways to generalize and to understand the dependence of biophysical phenomenon on time and length scales. No prior knowledge of biology is expected. This class is offered in Fall of even years (e.g. Fall '22, 24, etc.)
Prerequisites: (03-121 or 03-151) and (33-122 or 33-152 or 33-107 or 33-142 or 33-112 or 33-132)

03-442 Molecular Biology

Fall: 9 units
The structure and expression of eukaryotic genes are discussed, focusing on model systems from a variety of organisms including yeast, flies, worms, mice, humans, and plants. Topics discussed include (1) genomics, proteomics, and functional proteomics and (2) control of gene expression at the level of transcription of mRNA from DNA, splicing of pre-mRNA, export of spliced mRNA from the nucleus to the cytoplasm, and translation of mRNA.
Prerequisites: 03-221 Min. grade B or 03-330 Min. grade B or 03-220 Min. grade B

Course Website: http://www.cmu.edu/bio/undergrad/courses/index.html (http://www.cmu.edu/bio/undergrad/courses/)

03-445 Undergraduate Research

Fall and Spring
Students may investigate research problems under the supervision of members of the faculty. Permission of a faculty advisor required. **Students MUST contact bio-ungrad@andrew.cmu.edu and complete the application form in order to participate and amp; register.** BIO MAJORS: The Biology Undergraduate Office will send out the paperwork toyou on the first day of classes each semester. Paperwork and research mentor approval will be due the Friday before the add deadline. NON BIO MAJORS:Please contact the office (bio-ungrad@andrew.cmu.edu) to request the updated form.

03-451 Advanced Developmental Biology and Human Health

Fall: 9 units
This course will examine current research in developmental biology, focusing on areas that have important biomedical implications. The course will examine stem cell biology, cellular reprogramming, cell signaling pathways, tissue morphogenesis, and genetic/developmental mechanisms of birth defects and human diseases. Emphasis will be placed on the critical reading of recent, original research papers and classroom discussion, with supporting lectures by faculty.
Prerequisites: (03-240 Min. grade B or 03-709 Min. grade B or 03-320 Min. grade B) and (03-330 Min. grade B or 03-220 Min. grade B or 03-621 Min. grade B)

03-511 Computational Molecular Biology and Genomics

Fall: 9 units
An advanced introduction to computational molecular biology, using an applied algorithms approach. This course provides an in-depth treatment of the algorithmic foundations of computational molecular biology.
Prerequisites: (03-121 or 03-151) and 15-122

Course Website: http://www.cs.cmu.edu/~durand/03-711/

03-545 Honors Research

Spring: 9 units
This semester of research consists primarily of research and preparation of an acceptable written thesis. Oral presentation and defense of the thesis research will be required. This course ordinarily will be taken in the second semester of the senior year. Permission of the research advisor required. **Students MUST contact bio-ungrad@andrew.cmu.edu and complete the application form in order to participate and amp; register.**
Prerequisite: 03-445

03-600 Biotechnology or Biopharmaceutical Engineering Internship

All Semesters: 3 units
This course allows a student to gain biotechnology experience in a "real-world" setting. Internships vary widely in scope, but common to all is the chance to practice biotechnology skills acquired in the classroom. Typically, students seek and secure their own internships. Students are required to write written reflections summarizing their internship work and submit those to the course instructor.

03-601 Computational Biology Internship

All Semesters: 3 units
This course allows a student to gain computational biology experience in a "real-world" setting. Internships vary widely in scope, but common to all is the chance to practice computational biology skills acquired in the classroom. Typically, students seek and secure their own internships.

03-602 Quantitative Biology Internship

All Semesters: 3 units
This course allows a student to gain quantitative biology experience in a "real-world" setting. Internships vary widely in scope, but common to all is the chance to practice quantitative biology skills acquired in the classroom. Typically, students seek and secure their own internships. Students are required to write written reflections summarizing their internship work and submit those to the course instructor.

03-603 Applied Professional Skills for Computational Biologists

Fall and Spring: 3 units
This course gives Masters in Computational Biology students the opportunity to refine the professional skills necessary for a successful career in industry. This course, required for students completing the "Applied Study" option in the MS in Computational Biology program, provides opportunities to connect with computational biology professionals as part of industry outreach. The course will also include additional, customized review of application materials.

03-604 Professional Skills for Biotechnology, Quantitative & Computational Biology

Fall: 3 units
This course gives Masters students in Biological Sciences and related fields the opportunity to develop the professional skills necessary for a successful career in either academia or industry. The first set of topics will include assistance with elevator pitches, interview preparation, resume and cover letter writing, and presentation skills. The course will also guest speakers to connect with students professionally and to provide students with perspectives from within industry on regulatory compliance issues. The course is pass/fail only.

03-622 Modern Biology

Fall: 9 units
This is an introductory course that provides the basis for further studies in biochemistry, cell biology, genetics and molecular biology. This course emphasizes the chemical principles underlying biological processes and cell structures as well as the analysis of genetics and heredity from a molecular perspective. This is the introductory biology course for all science and non-science majors.

03-699 MS Research

All Semesters
A student enrolled in this course conducts an independent investigation on a project in a faculty advisor's lab. The project is selected from a major area of research study with the advice and approval of the faculty advisor. Students who are writing an honors thesis should enroll in 03-700 instead.

03-700 MS Honors Thesis Research

All Semesters
A student enrolled in this course conducts an independent investigation on a project in a faculty advisor's lab. The project is selected from a major area of research study with the advice and approval of the faculty advisor. This course is required of students who are enrolled in the Master of Science program and wish to write and defend a thesis. This course is only for students who are writing an honors thesis.

03-709 Applied Cell and Molecular Biology

Fall: 12 units
This course can serve a wide range of students, but it is primarily for students in Masters programs in life sciences. The purpose of this course is to review key cellular and molecular phenomenon in biological pathways with strong emphasis on latest experimental techniques used in applications including but not limited to disease diagnosis, therapeutics, large-scale genomic and proteomic analysis. Knowledge gained from this course will be both conceptual and analytical. Students will periodically write extensive research reports on select topics and give oral presentations on a select few, while critically analyzing primary literature.

03-711 Computational Molecular Biology and Genomics

Fall: 12 units
An advanced introduction to computational molecular biology, using an applied algorithms approach. This course provides an in-depth treatment of the algorithmic foundations of computational molecular biology.
Prerequisites: (03-121 or 03-151) and 15-122

Course Website: http://www.cs.cmu.edu/~durand/03-711/

03-713 Bioinformatics Data Integration Practicum

Spring: 6 units
This course provides a hands-on, self-directed experience dealing with biological data and integrating it to produce software and analyses that are of use to biologists. Data are taken from a variety of sources, including academic research labs, large scale public genomics projects and data from private industry partners. Students will be given a project and asked to design a solution using a combination of existing tools and their own developed software.

03-727 Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method

Fall: 12 units
An advanced introduction to the evolutionary concepts and bioinformatic skills that are central to molecular, cell, developmental, and microbiology. Proteins that share common ancestry also share functional properties. This is the guiding principle of model organism research and sequence-based bioinformatics. Evolutionary trees (phylogenies) and multiple sequence alignments provide evidence for predicting structural and functional constraints, sites of molecular interaction, and residues that confer functional specificity. In 2021, phylogenetics is emerging as an essential technique in metagenomics, cancer, and infectious disease, driven by technological advances such as high through-put sequencing and single-cell phenotyping. This course covers both the conceptual foundation and the practical skills of evolutionary bioinformatics. Students will acquire the "tree thinking" skills required for critical interpretation of phylogenetic analyses and figures in the literature and a rigorous understanding of phylogenetic inference methods. Theoretical knowledge will be complemented by hands-on experience with sequence data repositories, bioinformatic tools for database retrieval, sequence analysis, and tree building. Students will walk out of the course with the knowledge required to apply those tools correctly to messy, genuine data sets, and the ability to evaluate alternate hypotheses in light of these bioinformatic analyses. Students with a range of computational backgrounds are welcome.

Course Website: http://www.cs.cmu.edu/~durand/Phylogenetics/

03-728 Genome Editing Biotechnology

Fall: 6 units
How can we create genetically engineered cells, animals, plants, and even humans? This course will focus on the technologies that enable genome modification, with an emphasis on the recently developed CRISPR-Cas9 system. Specific topics will include an introduction to CRISPR technology and its history; DNA double strand break repair; Off target effects; Gene regulator CRISPRs; Alternate technologies; Ethics of modifying our genomes; Applications - cell screening; Applications - organism engineering; Applications - anti-HIV and immunotherapy; Overview of Gene therapy. Student in-class presentations will cover late-breaking topics and specific areas of student interest.
Prerequisites: 03-220 or 03-709 or 03-221 or 03-621

03-729 Entrepreneurship and protein-based drug development

Spring: 6 units
This is a course for students with background in biochemistry who want to learn about business opportunities and advances in protein-based treatments. As protein-based biologic drugs become more and more prevalent understanding the role of protein-protein interactions is vital for both design and production of biologic drugs. We will focus on the fundamentals of protein-interactions, giving examples of protein-protein interactions in important cellular pathways. We will also focus on how protein-protein interactions are used in the processing of biologic drugs, were antibody-Protein A interactions are key for the purification of antibody-based biologics. We will study case-studies of how the pharmaceutical industry develops biologics from conception, through FDA approval, to mass production.
Prerequisites: 03-709 or 03-231

03-730 Advanced Genetics

Spring: 12 units
This course considers selected current topics in molecular genetics at an advanced level. Emphasis is on classroom discussion of research papers. Topics are subject to change yearly. Examples of past topics include: nucleocytoplasmic trafficking of RNA in yeast, genome imprinting in mammals, molecular genetics of learning and memory in Drosophila, viral genomics, using yeast as a model system to study the molecular basis of human neurodegenerative diseases, and CRISPR/Cas9 genome editing.
Prerequisites: (03-330 Min. grade B or 03-220 Min. grade B or 03-221 Min. grade B) and (03-442 or 03-742)

03-738 Synthetic Biology

Fall: 6 units
This course discusses the design of artificial biological parts or systems for research, engineering and medical applications. The course is divided into two parts: top-down and bottom-up synthetic biology. In top-down synthetic biology, engineering of cells with new functions or new products with metabolic and genetic engineering techniques such as circuit building, directed evolution, CRISPR-Cas9 will be covered. In bottom-up synthetic biology, the assembly of molecules to obtain a specific biological output such as in vitro reconstitution of cellular machinery, cell free protein expression system and construction of artificial cells will be discussed.
Prerequisites: 03-231 or 03-232

03-740 Advanced Biochemistry

Spring: 12 units
This is a special topics course in which selected topics in biochemistry will be analyzed in depth with emphasis on class discussion of papers from the recent research literature. Topics change yearly. Recent topics have included single molecule analysis of catalysis and conformational changes; intrinsically disordered proteins; cooperative interactions of aspartate transcarbamoylase; and the mechanism of ribosomal protein synthesis.

03-741 Advanced Cell Biology

Spring: 12 units
This course covers fourteen topics in which significant recent advances or controversies have been reported. For each topic there is a background lecture by the instructor, student presentations of the relevant primary research articles and a general class discussion. Example topics are: extracellular matrix control of normal and cancer cell cycles, force generating mechanisms in trans-membrane protein translocation, signal transduction control of cell motility, and a molecular mechanism for membrane fusion.
Prerequisites: (03-240 or 03-320) and (03-232 or 03-231)

03-742 Advanced Molecular Biology

Fall: 12 units
The structure and expression of eukaryotic genes are discussed, focusing on model systems from a variety of organisms including yeast, flies, worms, mice, humans, and plants. Topics discussed include (1) genomics, proteomics, and functional proteomics and (2) control of gene expression at the level of transcription of mRNA from DNA, splicing of pre-mRNA, export of spliced mRNA from the nucleus to the cytoplasm, and translation of mRNA.

03-744 Membrane Trafficking

Spring: 9 units
While the focus of this course is to analyze membrane/protein traffic along both the biosynthetic and endocyctic pathways, our general goal is to teach students how to read and interpret the literature. In particular, we emphasize the conclusions and discuss their validity. The course is updated each year to include topics in which new and interesting developments have occurred. Emphasis is placed on how membrane traffic is regulated and where applicable how it is disrupted or subverted during disease processes. The course is of general interest to students, fellows, and faculty interested in cell biology, immunology, neurobiology, pharmacology and virology.
Prerequisites: 03-240 or 03-320

03-747 Proposal Preparation and Peer Review

Fall: 4 units
The concise and clear presentation of an experimental research plan is an essential skill for research scientists. This mini course is designed to introduce 2nd year students to the structure and preparation of a structured research proposal as well as formalize instruction in professional standards in research ethics, CV preparation, and scientific writing and data presentation. Course material is taken from actual grant proposals and previous years' qualifying exam proposals, as well as primary research publications and faculty grant proposals. The course is highly interactive, and students are required to participate in review of each others' work throughout the duration of the course. Coursework is expected to form the basis of the Ph.D. qualifying exam proposal in the winter of the second year.

03-750 Graduate Seminar

Fall and Spring: 1 unit
Each semester, all Department of Biological Sciences graduate students are required to register for and attend the weekly departmental Research Seminar (03-750; 1 unit). Graduate students are strongly urged to meet the speakers to broaden their knowledge of cutting-edge biological science, to discuss career paths and strategies and to make useful contacts; the faculty host can arrange group meetings for interested students.

03-751 Advanced Developmental Biology and Human Health

Fall: 12 units
This course will examine current research in developmental biology, focusing on areas that have important biomedical implications. The course will examine stem cell biology, cellular reprogramming, cell signaling pathways, tissue morphogenesis, and genetic/developmental mechanisms of birth defects and human diseases. Emphasis will be placed on the critical reading of recent, original research papers and classroom discussion, with supporting lectures by faculty.
Prerequisites: (03-240 Min. grade B or 03-320 Min. grade B or 03-621 Min. grade B) and (03-709 Min. grade B or 03-330 Min. grade B or 03-220 Min. grade B)

03-755 Graduate Research Seminar

Fall and Spring: 3 units
Each semester, all Departmental of Biological Sciences graduate students are required to register for and attend the weekly departmental Journal Club (Graduate Research Seminar 03-755; 3 units) during which students and faculty members give 25-minute presentations. Second-year students present a research paper or topic from the literature, and more senior students present their research results; typically, graduate students give four Journal Club presentations during their time in the department. Each succeeding year those students who speak at the Departmental Retreat or who are graduating by May of their fifth year are not required to present at Journal Club that year.

03-756 Graduate Independent Study

Fall and Spring
N/A

03-762 Advanced Cellular Neuroscience

Fall: 12 units
This course is an introductory graduate course in cellular neuroscience. As such it will assume little or no background but will rapidly progress to discussions of papers from the primarily literature. The structure of the course will be about half lectures and half discussions of new and classic papers from the primary literature. These discussions will be substantially led by students in the course. Topics covered will include ion channels and excitability, synaptic transmission and plasticity, molecular understanding of brain disease and cell biology of neurons. Assessment will be based on class participation, including performance on in-class presentations and a writing assignment.

03-763 Advanced Systems Neuroscience

Spring: 12 units
This course is a graduate version of 03-363. Students will attend the same lectures as the students in 03-363, plus an additional once weekly meeting. In this meeting, topics covered in the lectures will be addressed in greater depth, often through discussions of papers from the primary literature. Students will read and be expected to have an in depth understanding of several classic papers from the literature as well as current papers that illustrate cutting edge approaches to systems neuroscience or important new concepts. Use of animals as research model systems will also be discussed. Performance in this portion of the class will be assessed by supplemental exam questions as well as by additional homework assignments.
Prerequisites: 03-762 or 03-151 or 03-362 or 03-121

03-766 Advanced Neuropharmacology: Drugs, Brain and Behavior

Fall: 12 units
This course is designed to give students a comprehensive understanding of the major neurotransmitter systems in the brain. Students will explore qualitative and quantitative approaches to understanding how various neurotransmitters function as well as how they are modulated by endogenous and exogenous agents. The qualitative exploration will include basic principles of neural communication, signal transduction and second messenger systems, main classes of neurotransmitters, and the effects of medications and drugs of abuse. Quantitatively, we will explore the kinetics of neurotransmitter binding, affinity of different receptors for their neurotransmitters, and apply concepts of competitive, uncompetitive, and mixed inhibition to understanding the effects of exogenous agonists and antagonists on these receptors. Students will learn how these qualitative and quantitative biochemical processes affect the endocrine system, neuroinflammatory responses, addictive behaviors, and neurotoxic or degenerative conditions.

03-776 Molecular Techniques for Bioprocessing

Spring: 6 units
This course is the first in a sequence of two lab minis (03-776 and amp; 06-777) required for an MS degree in Biotechnology and Pharmaceutical Engineering. It is designed to teach you techniques used in molecular biology research, specifically those involved with upstream bioprocessing. In addition, you will further develop your skills in experimental design, quantitative reasoning, and critical analysis. While specific experiments may change from semester to semester, core topics include cloning techniques (plasmid isolation and characterization, PCR, restriction enzyme digests, gel electrophoresis) and cell culture (bacteria and mammalian). Experiments are designed to generate a eukaryotic cell line expressing a protein of interest. The follow-up lab, 06-777 for downstream bioprocessing, will build on the techniques and share some reagents.
Prerequisite: 03-709

03-791 Advanced Microbiology

Spring: 12 units
This course will use both lectures and current research literature in the area of Microbiology and Infectious Diseases to introduce such topics as prokaryotic cytoskeletal functions, the human microbiome and its impact, metabolic engineering, transposon mutagenesis for gene function elucidation, synthetic genome construction and applications, pathogenicity islands, functional and expression-based identification of pathogenicity determinants, horizontal gene transfer, regulatory RNAs, biofilm formation quorum sensing, and antimicrobial drug development.

03-871 Structural Biophysics

Fall: 12 units
This course (MB-1) is the first-semester core course for the joint CMU-Pitt graduate program in Molecular Biophysics and Structural Biology (MBSB). The physical properties of biological macromolecules and the methods used to analyze their structure and function are discussed in in-depth lectures. Topics covered include: protein architecture and folding; nucleic acid structures and energetics; structure determination by X-ray crystallography and NMR; optical spectroscopy with emphasis on absorption and fluorescence, NMR spectroscopic methods; other methods to characterize proteins and protein-ligand interactions, such as mass spectrometry, calorimetry, single-molecule manipulation and measurements, and surface plasmon resonance. Sufficient detail is given to allow the student to critically evaluate the current literature.
Prerequisites: (03-232 or 03-231) and (09-214 or 09-344) and (21-120 or 21-122)

03-900 Doctoral Thesis Research

All Semesters
Doctoral Thesis Research consists of an independent investigation on a project selected from a major area of research study with the advice and approval of the faculty advisor.

Department of Chemistry

Bruce Armitage, Department Head

Gizelle Sherwood, Director of Undergraduate Studies

Location: Doherty Hall 3304
www.chem.cmu.edu (http://www.chem.cmu.edu)

Mission Statement

Chemistry at Carnegie Mellon University is committed to making advances in the molecular sciences with lasting impact on foundational knowledge while tackling critical global challenges including sustainability, health, and quality of life.

Chemistry is an area of science involved with the study of the properties and reactions of substances ranging from living cells to subatomic particles. It is at the center of many scientific and technical fields, providing the fundamental knowledge and tools needed to address many of society's needs and to explore the unknown. Fields as diverse as genetic engineering, materials science and nanotechnology look to chemistry when they look to the future, for that is where the ultimate in understanding — the molecular level — resides.

Flexible Career Options

The chemistry profession is extraordinarily diverse, with career opportunities available in the chemical, petroleum, renewable energy, nuclear power, novel polymeric materials, metals, personal care and pharmaceutical industries, among many others. Chemistry plays an increasingly important role in the rapidly expanding biomedical and biotechnology industries. In addition to careers in industry and academia, many chemists find rewarding careers in the public sector in the laboratories of the National Institutes of Health, the Food and Drug Administration, the Environmental Protection Agency, the National Institute of Standards and Technology, and the Department of Energy as well as in consulting. Chemistry graduates also find employment in technical fields unrelated to science but where their problem solving and communication skills are highly valued.

Chemistry is a particularly suitable major for pre-medical and other pre-health profession students. Medical schools look favorably on the rigorous reasoning skills chemists develop, as evidenced by an excellent record for student admission to advanced education in these areas. An increasing number of our graduates are seeking careers in dentistry, pharmacy or pharmacology in addition to medicine. The Health Professions Program advises all Carnegie Mellon students considering careers in health fields. (See Health Professions Program description in this catalog for more information.) Chemistry is also excellent preparation for careers in law, especially for those with an interest in specializing in patent, intellectual property or environmental law. The curriculum has the flexibility to allow these students to participate in the CMU Washington Semester Program with the possibility of an internship in science policy should they desire. Students interested in industrial careers often combine their chemistry program with undergraduate courses in business administration or eventually go on to study for an M.B.A.

Any graduating class in chemistry reflects this diversity in career paths. Some recent examples are alums working as software engineers for Bloomberg in London and at MasterCard, in Healthcare Technical Services at Epic Systems, as a Research Scientist at Eli Lilly and as a Clinical Research Assistant at Children's Hospital of Pittsburgh. Others are finishing an M.S. degree in Materials Science and Engineering at Stanford University and attending law school at UCLA. Many are attending PhD programs in areas like biomaterials, nuclear engineering, polymer science and chemistry at top institutions including Stanford, UC Berkeley, Yale, MIT, and the University of Illinois at Urbana Champaign. Chemistry majors often comment with enthusiasm regarding the close-knit community, which includes the opportunity to network with alums through the Undergraduate Seminar program in chemistry.

Degree Pathways

The Department offers three Bachelor's degrees: the B.S. in Chemistry, the B.S. in Chemistry/Biological Chemistry Track and the B.A. in Chemistry. One third of the courses for the B.A. degree are free electives that may be taken in any of the departments of the University and therefore offers a high degree of flexibility. For the B.S. degrees, electives are often technical courses in chemistry or related fields of science, technology and engineering, such as biology, physics, mathematics, chemical, biomedical or materials science engineering or computer science, although they can be in other non-technical areas as well. It is possible to have all of the technical requirements completed after the junior year in the B.S. and B.A. degree programs, allowing students the flexibility to combine electives in the senior year into a focused program of specialization or to allow for additional breadth in their undergraduate experience. Students interested in graduate studies in chemistry may enroll in graduate courses. Those desiring immediate job placement may be interested in one or more of the formal options that supplement the chemistry B.S. degree. These are described in detail later in this section of the catalog. Carnegie Mellon has one of the strongest polymer science programs in the world and the undergraduate polymer science, materials chemistry or colloids, polymers and sciences options offer training that is particularly valuable for an industrial career. The Computational Chemistry option provides students with expertise in scientific computing that is highly sought after by employers in the pharmaceutical industry. Throughout the curriculum the use of computational tools is emphasized and students have access to state-of-the-art instrumentation in their courses and through undergraduate research as described below.

The overlap between the fields of chemistry and biological sciences continues to grow, with increased emphasis on synthetic chemicals that are used as probes or reporters of biological function and diagnostic and/or therapeutic agents. In addition, the application of sophisticated spectroscopic, structural and scanning probe/force methods on scales as low as single molecules is driving innovation and education at the chemistry/biology interface. Based on these trends the department offers the B.S. in Chemistry/Biological Chemistry Track to better prepare students for advanced studies and a job market that values knowledge and skills from both disciplines. A combination of advanced research-focused lecture course offerings and a novel laboratory course in bioorganic chemistry allows students to build the strong foundation typical of a successful chemistry major, while expanding out into applications of chemistry in the biological sciences. Students who complete the track will have been exposed to the latest research accomplishments and unanswered questions in biological chemistry while also gaining experience in experimental methods unique to research at this interface.

Honors Programs with Strong Research Focus

An honors program is offered for highly motivated undergraduates. It is designed primarily for students who wish to undertake a strong research-intensive program of study in contemporary chemistry. The B.S. in Chemistry with Departmental Honors requires the completion of at least one graduate level course in chemistry, a research project, and the writing and defense of a bachelor's level honors thesis. An advanced track leading to the B.S. in Chemistry with Departmental Honors together with a Master of Science degree in chemistry involves completion of five graduate level courses and a more extensive thesis research project. This degree path is especially attractive to students who plan to pursue an industrial career. With enough advanced placement credit or by carrying heavier than usual course loads, students can complete the Honors/M.S. degree program in 8 semesters, with research during one to two summers. The majority of openings in the chemical industry presently are at the Bachelors and Masters degree levels.

Additional majors (double majors) are available with nearly all other departments in the university provided the student can fit the required courses into the schedule. Generally, all the requirements for both departments must be met for an additional major (except for some courses with similar content). Programs are also available that lead to the degree B.S. in Chemistry with a minor in another discipline. Requirements for most minor programs are described by individual departments in this catalog. However, it is recommended that students who are interested in pursuing a minor as part of their degree consult with the department involved for the current requirements and further guidance about scheduling. Dual degree programs are available in which students receive two separate undergraduate degrees from two different departments in the University. These require students to complete at least 90 units of work per additional degree in addition to the units required for the first degree and the core curriculum from both colleges if the programs are in different units. Several five-year programs have been developed to allow a Carnegie Mellon undergraduate student to earn both a B.S. in Chemistry and a Master of Science degree in fields such as Health Care Policy and Management, Materials Science Engineering, Colloids, Polymers and Surfaces or Biomedical Engineering.

Study Abroad

Study abroad programs are available for chemistry majors and programs of one to two semesters can generally be accommodated without delaying time to graduation beyond 8 semesters. One example of a formal exchange program is spending two semesters at École Polytechnique Féderále de

Lausanne (EPFL) in Switzerland. Students can also study at the Carnegie Mellon campus in Qatar. Study abroad is encouraged by the chemistry department and can be arranged on an individual basis at universities throughout the world including Europe, Asia, Africa, New Zealand, and Australia during the academic year, the summer and winter or spring breaks. Students interested in study abroad should consult with their academic advisor and the MCS Study Abroad Advisor in the Office of International Education.

Undergraduate Research Opportunities

One of the most attractive features of the Department of Chemistry is the opportunity for students to interact with prominent research scientists in entry-level as well as advanced courses and in research. Undergraduate laboratory instruction takes place in a state-of-the-art facility located in Doherty Hall. Participation in undergraduate research is encouraged and qualified students may begin projects as early as their first year through research shadowing experiences. Chemistry majors interested in beginning research should consult with the Director of Undergraduate Studies to begin the process of identifying a research mentor. Approximately 90 to 98% of the graduating chemistry majors during the past ten years have taken part in research either for pay or for credit as part of their undergraduate training. Those who have not completed research experiences did so of their own choosing. Chemistry majors have been very successful in obtaining Small Undergraduate Research Grants (SURG) and Summer Undergraduate Research Fellowships (SURF) from the University to help support their research projects. Several students each summer obtain iSURF support, International Summer Undergraduate Research Fellowships, to work with research collaborators abroad.

Faculty in the Department of Chemistry are leading the way in the use of computer-controlled instrumentation for synthesis and analysis of chemical compounds. In addition to automated science capabilities in individual labs, our faculty are engaged in the design and construction of the very first Academic Cloud Lab (https://cloudlab.cmu.edu/) that is housed at Carnegie Mellon University. This facility will allow graduate and undergraduate researchers to design and run experiments remotely, with the work carried out by robots and trained technicians according to computer code written by the researchers. In addition to use in research, our faculty have developed experiments within existing courses and created stand-alone courses utilizing the Emerald Cloud Lab; this coursework will transition to the Carnegie Mellon facility once it is fully operational.

Program Outcomes

The faculty members of the Department of Chemistry have approved the following as a statement of our learning outcomes for recipients of an undergraduate degree in chemistry.

Upon graduation recipients of the BS or BA degree in Chemistry will:

Foundational knowledge/theory

- Have a firm foundation in the quantitative and computational thinking that underlies chemistry, including use of modern computational tools.
- Have a firm foundation in the theories and models that form the basis for reasoning about molecular systems.
- Understand how the different subdisciplines of chemistry relate to and complement one another.
- Be able to apply chemical reasoning across disciplines, such as biology, environmental science, polymer and materials science, nanotechnology, and engineering.

Practical/Experimental

- Understand that chemistry is fundamentally an experimental science, and be able to identify or create an appropriate model, formulate a hypothesis, choose an appropriate set of tools and techniques, and design an experiment that tests the hypothesis and analyze the results from that experiment drawing sound scientific conclusions from the results obtained.
- Be proficient in the use of both classical and modern tools for analysis of chemical systems.
- Be able to design and carry out synthesis of both organic and inorganic systems.
- Be able to use experience and knowledge gained through theoretical and practical design projects to conduct further research.
- Know and follow the proper procedures and regulations for safe handling and use of chemicals and chemical equipment.

Communication

- Be able to convey information, both orally and in writing, to a range of audience levels and for a variety of purposes.
- Understand how scientific information is shared between peers in modern science, including responsible conduct for acknowledging prior and current contributions.
- Be able to locate, identify, understand and critically evaluate the chemical literature.
- Develop the interpersonal skills to function cooperatively in a team setting.

Society and ethics

- Understand the opportunities and consequences of chemistry for the environment and society for both short term and long-term sustainability.
- Understand and apply ethics and values to all professional activities.

Professional development

- Develop an understanding of career opportunities both within and outside of chemistry, including through contacts with faculty, the career and professional development center and alumni.
- Be prepared to pursue a life and career that builds on their experiences at Carnegie Mellon to achieve their personal goals and to contribute positively to society.

B.S. in Chemistry (and requirements for additional major in chemistry)

The majority of undergraduate degrees awarded by the Department of Chemistry are Bachelor of Science degrees. This degree program provides the most appropriate preparation for further graduate study and for industrial positions in research and development or analytical chemistry. The curriculum provides a strong foundation in the fundamental areas of study in chemistry: organic, physical, inorganic and analytical chemistry, along with a rich set of research-focused, instrumentation intensive laboratory experiences aligned with those areas. Students interested in less technical areas of employment or graduate study in areas such as business, policy or law may find the Bachelor of Arts degree a more suitable alternative.

The suggested curriculum recommends that the required technical courses be completed at the earliest opportunity, however students have considerable flexibility to postpone these courses in favor of electives, allowing compatibility with the programs of other departments. In designing such programs for a minor or additional major with chemistry, students should note that certain required chemistry courses only are offered in specific semesters, not both. These include the Fall-only courses , 09-219 Modern Organic Chemistry, 09-321 Laboratory III: Molecular Design and Synthesis and 09-323 Bioorganic Chemistry Laboratory and 09-344 Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry as well as the Spring-only courses 09-331 Modern Analytical Instrumentation, 09-220 Modern Organic Chemistry II, 09-345 Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry and 09-348 Inorganic Chemistry. Also, in some cases, a course that is normally scheduled for the fall may be changed to a spring course (or the inverse) due to a departmental curriculum change or faculty availability.

Curriculum for the B.S. in Chemistry and Requirements for an Additional Major in Chemistry

This catalog and the sample schedules presented are intended to be used by students in the first year class entering in the fall of 2024. Upperclass students should refer to the appropriate previous version of the catalog published during their first year for the requirements that are specific to them.

The technical breadth requirement of the MCS core curriculum requires a minimum of four technical courses outside of the student's primary major. Chemistry majors must at minimum take the following non-chemistry technical courses:

Technical Breadth Requirements		Units
33-121	Physics I for Science Students	12
33-122	Physics II for Biological Sciences & Chemistry Students	9
03-121	Modern Biology	9
or 03-231	Honors Biochemistry	
or 03-232	Biochemistry I	
15-110	Principles of Computing or other approved upper level programming course	10
or 15-112	Fundamentals of Programming and Computer Science	

21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	

Students should complete this technical core as early as possible and preferably by the end of their fifth semester. AP credit cannot be used to fulfill the technical breadth requirements for the core though AP classes can be used to fulfill prerequisites for chemistry classes. Please note that if you have completed the courses in any single category solely by AP credit, you must take an approved upper level course to fulfill the technical core requirement.

The non-technical breadth requirements for MCS students includes Interpretation and Argument (76-101, 9 units), four courses with a minimum of 36 units from the arts, humanities or social sciences and a course of at least 9 units from an approved list in the category of Cultural/Global understanding, a course in the Science and Society category of at least 6 units, a total of five ENGAGE courses including three ENGAGE in Wellness courses, ENGAGE in Wellness: Looking Inward (38-230, 1 units), ENGAGE in Wellness: Looking Outward (38-330, 1 units) and ENGAGE in Wellness: Looking Forward (38-430, 1 units), as well as ENGAGE in Service (38-110, 1 units) and ENGAGE in the Arts (38-220, 2 units) plus EUREKA!: Discovery and Its Impact (38-101, 6 units) the MCS first-year seminar and 99-101 Core@CMU, for a minimum of 75 units.

The Science and Society requirement as well as the ENGAGE courses must be finished **prior** to your final semester at CMU (no later than your penultimate semester). The Science and Society requirement can be fulfilled in numerous ways via MCS classes and other disciplinary courses that can also fulfill other requirements for your degree (but can NOT double count within the general education categories i.e. a course used to fulfill Science and Society cannot also fulfill your Cultural Analysis requirement or count towards your 36 units of non-technical electives). In the chemistry department courses currently approved to fulfill the Science and Society requirement that can also count as a chemistry elective are 09-510 Chemistry and Sustainability (or the graduate version,09-710), 09-381 Environmental Systems on a Changing Planet and 09-403 Hooked: The Chemical Basis of Drug Addiction. A more expanded listing will be maintained by the MCS Dean's Office (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/index.html (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/)).

For more information on allowed courses in the arts, humanities and social sciences and electives in the Cultural/Global Understanding category refer to the MCS section of this catalog.

The following are only meant to represent sample schedules. Students should always consult with their academic advisor to discuss an individualized plan to meet their academic goals.

Freshman Year

Fall		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
21-120	Differential and Integral Calculus	10
33-121	Physics I for Science Students	12
76-101	Interpretation and Argument	9
38-101	EUREKA!: Discovery and Its Impact	6
99-101	Core@CMU	3
		50

Students interested in majoring in chemistry who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II via a prerequisite waiver.

There are some elective laboratory courses offered for MCS students in the first year. These include 03-117 Frontiers, Analysis, and Discovery in Biological Sciences or 09-115 Introduction to Undergraduate Research in Chemistry. The maximum units allowed during the first semester is 54; therefore, students wishing to take a lab should take an alternate technical course to Physics I such as 15-110 or 03-121 so that their unit total is lower.

Spring		Units
09-106	Modern Chemistry II Chemistry majors who place out of 09-106 can take 09-348 Inorganic Chemistry, 09-510 Chemistry and Sustainability as a chemistry elective or 09-116 a course that will allow you to shadow upperclass mentors in undergraduate research in chemistry. Chemistry majors who feel they are ready for an undergraduate research experience should meet with the Director of Undergraduate Studies. These opportunities are more prevalent in the summer after your first year or sophomore year.	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	
33-121	Physics I for Science Students	12
or 03-121	Modern Biology	
or 15-110	Principles of Computing	
xx-xxx	Arts, Humanities and Social Sciences Course 1	9
xx-xxx	Free Elective	9.0
		50

Sophomore Year

Fall		Units
09-201	Undergraduate Seminar I	1
09-219	Modern Organic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
33-122	Physics II for Biological Sciences & Chemistry Students Course is a prerequisite for 09-331, normally taken in the spring of the junior year	9
xx-xxx	Arts, Humanities and Social Sciences Course 2	9
		41

Spring		Units
09-202	Undergraduate Seminar II: Safety and Environmental Issues for Chemists	1
09-220	Modern Organic Chemistry II	10
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-348	Inorganic Chemistry (Students wishing to pursue careers in the health professions or are pursuing the Biological Chemistry Track may wish to take biochemistry, 03-232, and delay inorganic until the junior or senior year spring semester)	10
38-230	ENGAGE in Wellness: Looking Inward	1
xx-xxx	Arts, Humanities and Social Sciences Course 3	9
		43

Reminder about Flexible Scheduling: Student feedback indicates that the junior year BS schedule can feel quite intense as you move into the more mathematical and physical chemistry oriented curriculum, especially if you are also engaged in undergraduate research. Remember that the senior year in chemistry is essentially open for free electives. You may use this flexibility to spread out your junior year requirements over four semesters rather than two; though you should be careful about moving too many courses to the senior year as that may create additional stress at a time when you are preparing to move forward from CMU. You should consult with your academic advisor to explore alternative schedules if you are interested.

Junior Year

Fall		Units
09-301	Undergraduate Seminar III	1
09-231	Mathematical Methods for Chemists Math methods is a co-requisite for 09-344 and a prerequisite for 09-345 (spring). If you move math methods to the fall of your senior year, you must also move 09-344, 09-345 and 09-322 to the senior year.	9
09-321	Laboratory III: Molecular Design and Synthesis This lab class is not a prerequisite for 09-322; it can be moved to the fall of your senior year without impacting the spring junior year courses.	12
or 09-323	Bioorganic Chemistry Laboratory	

09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry Quantum is a prerequisite for Lab IV. If you move Quantum to the fall of the senior year, you must move Lab IV to the spring of the senior year. 09-344 is not a prerequisite for 09-345 (spring).	9
38-330	ENGAGE in Wellness: Looking Outward	1
xx-xxx	Arts, Humanities and Social Sciences Course 4	9
		41

Spring		Units
09-302	Undergraduate Seminar IV	1
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV.	9
09-331	Modern Analytical Instrumentation This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV.	9
xx-xxx	Cultural/Global Understanding Requirement	9
xx-xxx	Approved Science and Society elective. This course can be scheduled at any point during your studies but prior to your final semester..	6-9
		46-49

Senior Year

Fall		Units
09-401	Undergraduate Seminar V	1
09-xxx	Chemistry Elective (see notes on electives)	9
38-110	ENGAGE in Service	1
38-220	ENGAGE in the Arts	2
38-430	ENGAGE in Wellness: Looking Forward	1
xx-xxx	Free Electives	30
		44

Spring		Units
09-402	Undergraduate Seminar VI	3
09-xxx	Chemistry Elective (see notes on electives)	9
xx-xxx	Free Electives	27
		39

Distribution of Units for B.S. in Chemistry and Requirements for An Additional Major in Chemistry

Minimum Total Chemistry Units 160; See distribution below

Required Chemistry Courses* Units		
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-219	Modern Organic Chemistry	10
09-220	Modern Organic Chemistry II	10
09-231	Mathematical Methods for Chemists	9
09-331	Modern Analytical Instrumentation	9
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-348	Inorganic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-321	Laboratory III: Molecular Design and Synthesis	12
or 09-323	Bioorganic Chemistry Laboratory	
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12
09-xxx	Chemistry Seminars	8
09-xxx	Chemistry Electives	18

* These, plus 33-121 Physics I for Science Students and 33-122 Physics II for Biological Sciences & Chemistry Students, are the required courses for students earning an additional major in chemistry.

Students who transfer into the department and have taken 09-217 Organic Chemistry I and/or 09-218 Organic Chemistry II, will be required to complete units of 09-435 Independent Study Chemistry, 1 unit per course, under the supervision of the instructor(s) for 09-219 and/or 09-220 in order to master the course content missed in this course sequence.

Students who transfer into the department and have taken 09-207 Techniques in Quantitative Analysis and/or 09-208 Techniques for Organic Synthesis and Analysis will be required to take a 3 unit transition course (09-215 Chemistry Tech I to Lab I Transition for 09-207 and/or 09-216 Chemistry Tech II to Lab II Transition for 09-208) to fulfill the major requirements for 09-221 and/or 09-222.

Chemistry courses required for the BS degree and the additional major in chemistry that are numbered 09-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances.

Other Requirements	**Units**
Biology (Modern Biology or Biochemistry)	**9**
Computer Science	**10**
Mathematics	**20**
Physics	**21**
Interpretation and Argument	**9**
Arts, Humanities and Social Sciences Courses	**36**
Cultural/Global Understanding	**9**
EUREKA! (First-year seminar)	**6**
Science and Society requirement	**6**
ENGAGE in Service	**1**
ENGAGE in Wellness Courses (three courses)	**3**
ENGAGE in the Arts	**2**
Core@CMU	**3**
Free Electives	**65**
Minimum number of units required for the degree:	**360**

The above B.S. curriculum recommends a range of 41–50 units per semester to meet the minimum degree requirement of 360 units. Students are strongly encouraged to take extra elective courses (except in the first year) in whatever subjects they wish in order to enrich their backgrounds and enhance their educational experience.

Some students may need to earn more than 360 units to complete their degree. Usually this happens when students earn AP Credit for a course (for example 09-105) and then take a class with the same or similar content (take 09-105 at CMU or 09-107). You cannot count 20 units towards a 10-unit requirement so this student would need to earn 370 total units.

Notes on Electives

Chemistry Electives

A minimum of 18 units of chemical electives is required.

Chemical electives can be satisfied by 09-445 Undergraduate Research, or by most other chemistry courses 09-3xx or higher, undergraduate or graduate, for which the student has the necessary prerequisites, or by 03-231/03-232 Biochemistry I. Biochemistry also fulfills the Life Sciences requirement for the MCS technical breadth requirement. 09-435 Independent Study Chemistry, may only be used to fulfill this requirement with permission of the Director of Undergraduate Studies. Certain interdisciplinary courses (e.g. 39-xxx) relating to chemistry can also be used with permission by the Director of Undergraduate Studies. Chemistry electives are intended to enhance a student's technical knowledge in chemistry. Some chemistry courses are more interdisciplinary in nature and/or less technical in content. This applies to 09-510 Chemistry and Sustainability and 09-381 Environmental Systems on a Changing Planet. (Note: the nine-unit 09-291 cannot count as a chemistry elective.) Only one of these two courses may be counted towards fulfillment of 18 units of chemistry electives.

The scheduling of these electives can vary and students should check with the department offering the course to see which courses are offered in any given year or semester and with the Director of Undergraduate Studies in the Department of Chemistry to ascertain whether the course is an acceptable chemistry elective.

Free Electives

Free electives are defined as including any course offered by Carnegie Mellon except those in science or engineering fields that are primarily intended for non-majors. A maximum of 9 units total of Physical Education, StuCo and/or ROTC courses combined can be counted as free elective units. The Chemistry Department does not require technical electives.

B.A. in Chemistry

The curriculum for the B.A. degree provides students with the opportunity to take a substantial number of elective and non-technical courses. Certain chemistry, math, and other technical courses required for the B.S. degree are replaced by free electives, making this degree an ideal choice for those who wish to earn an additional major with one of the departments in the College of Humanities and Social Sciences, College of Fine Arts, or with the Business Administration program, though this is not a requirement. It is also attractive for students wishing to pursue careers in dentistry or pharmacy, career paths that require a broader preparation at the undergraduate level and hence more coursework outside of chemistry. Students may earn one or more of the options as described for B.S. degree candidates, providing they complete the courses listed.

The suggested curriculum recommends that the required technical courses be completed at the earliest opportunity, however students have considerable flexibility to postpone these courses in favor of electives, allowing compatibility with the programs of other departments. In designing such programs for a minor or additional major with chemistry, students should note that certain required chemistry courses only are offered in specific semesters, not both. These include the Fall-only courses , 09-219 Modern Organic Chemistry, 09-321 Laboratory III: Molecular Design and Synthesis and 09-323 Bioorganic Chemistry Laboratory and the Spring-only courses 09-331 Modern Analytical Instrumentation, 09-220 Modern Organic Chemistry II and 09-348 Inorganic Chemistry. Also, in some cases, a course that is normally scheduled for the fall may be changed to a spring course (or the inverse) due to a departmental curriculum change or faculty availability.

Curriculum

This catalog and the sample schedules presented are intended to be used by students in the first year class entering in the fall of 2024. Upperclass students should refer to the appropriate previous version of the catalog published during their first year for the requirements that are specific to them.

The technical breadth requirement of the MCS core curriculum requires a minimum of four technical courses outside of the student's primary major. Chemistry majors must at minimum take the following non-chemistry technical courses:

Technical Breadth Requirements		Units
33-121	Physics I for Science Students	12
33-122	Physics II for Biological Sciences & Chemistry Students	9
03-121	Modern Biology	9
or 03-231	Honors Biochemistry	
or 03-232	Biochemistry I	
15-110	Principles of Computing or any approved upper level CS class	10
or 15-112	Fundamentals of Programming and Computer Science	
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	

Students should complete this technical core as early as possible and preferably by the end of their fifth semester. AP credit cannot be used to fulfill the technical breadth requirements for the core though AP classes can be used to fulfill prerequisites for chemistry classes.

The non-technical breadth requirements for MCS students includes Interpretation and Argument (76-101, 9 units), four courses with a minimum of 36 units from the arts, humanities or social sciences and a course of at least 9 units from an approved list in the category of Cultural/Global understanding, a course in the Science and Society category of at least 6 units, a total of five ENGAGE courses including three ENGAGE in Wellness courses, ENGAGE in Wellness: Looking Inward (38-230, 1 units), ENGAGE in Wellness: Looking Outward (38-330, 1 units) and ENGAGE in Wellness: Looking Forward (38-430, 1 units), as well as ENGAGE in Service (38-110, 1 units) and ENGAGE in the Arts (38-220, 2 units) plus EUREKA!: Discovery and Its Impact (38-101, 6 units) the MCS first-year seminar and 99-101 Core@CMU, for a minimum of 75 units.

The Science and Society requirement as well as the ENGAGE courses must be finished **prior** to your final semester at CMU (no later than your penultimate semester). The Science and Society requirement can be fulfilled in numerous ways via MCS classes and other disciplinary courses that can also fulfill other requirements for your degree (but can NOT double count within the general education categories i.e. a course used to fulfill Science and Society cannot also fulfill your Cultural Analysis requirement or count towards your 36 units of non-technical electives). In the chemistry department courses currently approved to fulfill the Science and Society requirement that can also count as a chemistry elective are 09-510 Chemistry and Sustainability (or the graduate version,09-710), 09-381 Environmental Systems on a Changing Planet and 09-403 Hooked: The Chemical Basis of Drug Addiction. A more expanded listing will be maintained by the MCS Dean's Office (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/index.html (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/)).

For more information on allowed courses in the arts, humanities and social sciences and electives in the Cultural/Global Understanding category refer to the MCS section of this catalog.

The following are only meant to represent sample schedules. Students should always consult with their academic advisor to discuss an individualized plan to meet their academic goals.

First Year

Fall		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
21-120	Differential and Integral Calculus	10
33-121	Physics I for Science Students	12
76-101	Interpretation and Argument	9
38-101	EUREKA!: Discovery and Its Impact	6
99-101	Core@CMU	3
		50

Students interested in majoring in chemistry who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

There are some elective laboratory courses offered for MCS students in the first year. These include 03-117 Frontiers, Analysis, and Discovery in Biological Sciences and 09-115 Introduction to Undergraduate Research in Chemistry. The maximum units allowed during the first semester is 54; therefore, students wishing to take a lab should take an alternate technical course to Physics I such as 15-110 or 03-121 so that their unit total is lower.

Spring		Units
09-106	Modern Chemistry II *	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	
15-110	Principles of Computing	10
or 33-121	Physics I for Science Students	
or 03-121	Modern Biology	
xx-xxx	Arts, Humanities and Social Sciences Course 1	9
xx-xxx	Free Elective	9
		48

* Chemistry majors who place out of 09-106 can take 09-348 Inorganic Chemistry, 09-510 Chemistry and Sustainability as a chemistry elective, or other courses yet to be announced. Chemistry majors who feel they are ready for an undergraduate research experience should meet with the Director of Undergraduate Studies. These opportunities are more prevalent in the summer after your first year or sophomore year.

Sophomore Year

Fall		Units
09-201	Undergraduate Seminar I	1
09-219	Modern Organic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12

33-122	Physics II for Biological Sciences & Chemistry Students This course is required before graduation but need not be taken this semester.	9
xx-xxx	Arts, Humanities and Social Sciences Course 2	9
		41

Spring		Units
09-202	Undergraduate Seminar II: Safety and Environmental Issues for Chemists	1
09-220	Modern Organic Chemistry II	10
09-222	Laboratory II: Organic Synthesis and Analysis	12
38-230	ENGAGE in Wellness: Looking Inward	1
xx-xxx	Arts, Humanities and Social Sciences Course 3	9
xx-xxx	Free Elective	9
		42

Junior Year

Fall		Units
09-301	Undergraduate Seminar III	1
09-321	Laboratory III: Molecular Design and Synthesis	12
or 09-323	Bioorganic Chemistry Laboratory	
03-121	Modern Biology	9
or 15-110	Principles of Computing	
38-330	ENGAGE in Wellness: Looking Outward	1
xx-xxx	Arts, Humanities and Social Sciences Course 4	9
xx-xxx	Free Elective	9
		41

Spring		Units
09-302	Undergraduate Seminar IV	1
09-348	Inorganic Chemistry	10
09-331	Modern Analytical Instrumentation	9
xx-xxx	Cultural/Global Understanding Requirement	9
xx-xxx	Approved Science and Society elective. This course can be scheduled at any point during your studies but prior to your final semester.	6-9
xx-xxx	Free Elective	9
		44-47

Senior Year

Fall		Units
09-401	Undergraduate Seminar V	1
09-xxx	Chemistry Elective	9
38-430	ENGAGE in Wellness: Looking Forward	1
38-110	ENGAGE in Service	1
38-220	ENGAGE in the Arts	2
xx-xxx	Free Electives	28
		42

Spring		Units
09-402	Undergraduate Seminar VI	3
09-xxx	Chemistry Elective	9
xx-xxx	Free Electives	40
		52

Distribution of Units

Minimum Total Chemistry Units 121; See distribution below:

Required Chemistry Courses		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-219	Modern Organic Chemistry	10
09-220	Modern Organic Chemistry II	10
09-331	Modern Analytical Instrumentation	9
09-348	Inorganic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-321	Laboratory III: Molecular Design and Synthesis	12
or 09-323	Bioorganic Chemistry Laboratory	
09-xxx	Chemistry Seminars	8
09-xxx	Chemistry Electives	18

09-322 Laboratory IV: Molecular Spectroscopy and Dynamics may be taken in lieu of 09-321 Laboratory III: Molecular Design and Synthesis or 09-323 Bioorganic Chemistry Laboratory. However the student must complete the necessary pre- and co-requisites of 09-231, 09-344,and 09-345. In this case 09-345 and 09-344 will count as chemistry electives towards the B.A. degree.

Students who transfer into the department and have taken 09-217 Organic Chemistry I, and/or 09-218 Organic Chemistry II, will be required to complete units of 09-435 Independent Study Chemistry, 1 unit per course, under the supervision of the instructor(s) for 09-219 and/or 09-220 in order to master the course content missed in this course sequence.

Students who transfer into the department and have taken 09-207 Techniques in Quantitative Analysis and/or 09-208 Techniques for Organic Synthesis and Analysis will be required to take a 3 unit transition course (09-215 Chemistry Tech I to Lab I Transition for 09-207 and/or 09-216 Chemistry Tech II to Lab II Transition for 09-208) to fulfill the major requirements for 09-221 and/or 09-222.

Chemistry courses required for the B.A. degree that are numbered 09-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances.

Other Requirements	**Units**
Biology (either Modern Biology or Biochemistry)	**9**
Computer Science	**10**
Mathematics	**20**
Physics	**21**
Interpretation and Argument	**9**
Arts, Humanities and Social Sciences courses	**36**
Cultural/Global Understanding	**9**
EUREKA! (First year seminar)	**6**
Science and Society Elective	**6**
ENGAGE in Wellness (3 courses)	**3**
ENGAGE in Service	**1**
ENGAGE in the Arts	**2**
CORE@CMU	**3**
Free Electives	**104**
Minimum number of units for the degree	**360**

The above B.A. curriculum recommends a range of 40–50 units per semester. The total units actually taken may exceed the 360 unit minimum, but students are strongly encouraged to take the extra elective courses in whatever subjects they wish in order to enrich their backgrounds and enhance their educational experience.

Some students may need to earn more than 360 units to complete their degree. Usually this happens when students earn AP Credit for a course (for example 09-105) and then take a class with the same or similar content (take 09-105 at CMU or 09-107). You cannot count 20 units towards a 10-unit requirement so this student would need to earn 370 total units.

Notes on Electives

Chemistry Electives

A minimum of 18 units of chemical electives is required.

Chemical electives can be satisfied by 09-445 Undergraduate Research, or by most other chemistry courses 09-3xx or higher, undergraduate or graduate, for which the student has the necessary prerequisites, or by 03-231/03-232 Biochemistry I. Biochemistry also fulfills the Life Sciences requirement for the MCS technical breadth requirement. 09-435 Independent Study Chemistry, may only be used to fulfill this requirement with permission of the Director of Undergraduate Studies. Certain interdisciplinary courses (e.g. 39-xxx) relating to chemistry can also be used with permission by the Director of Undergraduate Studies. Chemistry electives are intended to enhance a student's technical knowledge in chemistry. Some chemistry courses are more interdisciplinary in nature and/or less technical in content. This applies to 09-510 Chemistry and Sustainability and 09-381 Environmental Systems on a Changing Planet.

(Note: the 9-unit course 09-291 cannot count as a chemistry elective.) Only one of these two courses may be counted towards fulfillment of 18 units of chemistry electives.

The scheduling of these electives can vary and students should check with the department offering the course to see which courses are offered in any given year or semester and with the Director of Undergraduate Studies in the Department of Chemistry to ascertain whether the course is an acceptable chemistry elective.

Free Electives

Free electives are defined as including any course offered by Carnegie Mellon except those in science or engineering fields that are primarily intended for non-majors. A maximum of 9 units total of Physical Education and/or ROTC courses combined can be counted as free elective units. The Chemistry Department does not require technical electives.

B.S. in Chemistry/Biological Chemistry Track

This degree is ideal for students who wish to better prepare themselves for advanced studies in biological chemistry or biomedical fields and a job market that values knowledge and skills from both disciplines. A combination of advanced research-focused lecture course offerings and a novel laboratory course modeling the drug discovery process will allow students to build the strong foundation typical of a successful chemistry major, while expanding out into applications of chemistry in the biological sciences.

The suggested curriculum recommends that the required technical courses be completed at the earliest opportunity, however students have considerable flexibility to postpone these courses in favor of electives, allowing compatibility with the programs of other departments. In designing such programs for a minor or additional major with chemistry, students should note that certain required chemistry courses only are offered in specific semesters, not both. These include the Fall-only courses , 09-219 Modern Organic Chemistry, 09-321 Laboratory III: Molecular Design and Synthesis and 09-323 Bioorganic Chemistry Laboratory and 09-344 Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry as well as the Spring-only courses 09-331 Modern Analytical Instrumentation, 09-220 Modern Organic Chemistry II, 09-345 Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry and 09-348 Inorganic Chemistry. Also, in some cases, a course that is normally scheduled for the fall may be changed to a spring course (or the inverse) due to a departmental curriculum change or faculty availability.

Curriculum

This catalog and the sample schedules presented are intended to be used by students in the first year class entering in the fall of 2024. Upperclass students should refer to the appropriate previous version of the catalog published during their first year for the requirements that are specific to them.

The technical breadth requirement of the MCS core curriculum requires a minimum of four technical courses outside of the student's primary major. Chemistry majors in the Biological Chemistry Track must at minimum take the following non-chemistry technical courses: Physics I for Science Students (33-121, 12 units), Physics II for Biological Sciences & Chemistry Students (33-122, 9 units), Modern Biology (03-121, 9 units), Principles of Computing (15-110, 10 units) (or other approved programming course), 21-120 Differential and Integral Calculus (10 units) and Integration and Approximation (21-122, 10 units) **or** Calculus II for Biologists and Chemists (21-124, 10 units). Students should complete this technical core as early as possible and preferably by the end of their fifth semester. AP credit cannot be used to fulfill the technical breadth requirements for the core though AP classes can be used to fulfill prerequisites for chemistry classes.

The non-technical breadth requirements for MCS students includes Interpretation and Argument (76-101, 9 units), four courses with a minimum of 36 units from the arts, humanities or social sciences and a course of at least 9 units from an approved list in the category of Cultural/Global understanding, a course in the Science and Society category of at least 6 units, a total of five ENGAGE courses including three ENGAGE in Wellness courses, ENGAGE in Wellness: Looking Inward (38-230, 1 units), ENGAGE in Wellness: Looking Outward (38-330, 1 units) and ENGAGE in Wellness: Looking Forward (38-430, 1 units), as well as ENGAGE in Service (38-110, 1 units) and ENGAGE in the Arts (38-220, 2 units) plus EUREKA!: Discovery and Its Impact (38-101, 6 units) the MCS first-year seminar and 99-101 Core@CMU, for a minimum of 75 units.

The Science and Society requirement as well as the ENGAGE courses must be finished **prior** to your final semester at CMU (no later than your penultimate semester). The Science and Society requirement can be fulfilled in numerous ways via MCS classes and other disciplinary courses that can also fulfill other requirements for your degree (but can NOT double count within the general education categories i.e. a course used to fulfill Science and Society cannot also fulfill your Cultural Analysis requirement or count towards your 36 units of non-technical electives). In the chemistry department courses currently approved to fulfill the Science and Society requirement that can also count as a chemistry elective are 09-510 Chemistry and Sustainability (or the graduate version,09-710), 09-381 Environmental Systems on a Changing Planet and 09-403 Hooked: The Chemical Basis of Drug Addiction. A more expanded listing will be maintained by the MCS Dean's Office (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/index.html (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/)).

For more information on allowed courses in the arts, humanities and social sciences and electives in the Cultural/Global Understanding category refer to the MCS section of this catalog.

The following are only meant to represent sample schedules. Students should always consult with their academic advisor to discuss an individualized plan to meet their academic goals.

Freshman Year

Fall		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
21-120	Differential and Integral Calculus	10
33-121	Physics I for Science Students	12
76-101	Interpretation and Argument	9
38-101	EUREKA!: Discovery and Its Impact	6
99-101	Core@CMU	3
		50

Students interested in majoring in chemistry who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

There are some elective laboratory courses offered for MCS students in the first year. These include 03-117 Frontiers, Analysis, and Discovery in Biological Sciences or 09-115 Introduction to Undergraduate Research in Chemistry. The maximum units allowed during the first semester is 54; therefore, students wishing to take a lab should take an alternate technical course to Physics I such as 15-110 or 03-121 so that their unit total is lower.

Spring		Units
09-106	Modern Chemistry II *	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	
03-121	Modern Biology	9
or 33-121	Physics I for Science Students	
or 15-110	Principles of Computing	
xx-xxx	Arts, Humanities and Social Sciences Course 1	9
xx-xxx	Free Elective	5
		43

* Chemistry majors who place out of 09-106 can take 09-348 Inorganic Chemistry, 09-510 Chemistry and Sustainability as a chemistry elective, or other courses yet to be announced. Chemistry majors who feel they are ready for an undergraduate research experience should meet with the Director of Undergraduate Studies. These opportunities are more prevalent in the summer after your first year or sophomore year.

Sophomore Year

Fall		Units
09-201	Undergraduate Seminar I	1
09-219	Modern Organic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
33-122	Physics II for Biological Sciences & Chemistry Students Course is a prerequisite for 09-331, normally taken in the spring of the junior year	9
03-220	Genetics or other biological chemistry elective.	9

xx-xxx	Arts, Humanities and Social Sciences Course 2	9
		50

Spring		Units
09-202	Undergraduate Seminar II: Safety and Environmental Issues for Chemists	1
09-220	Modern Organic Chemistry II	10
09-222	Laboratory II: Organic Synthesis and Analysis	12
03-232	Biochemistry I	9
38-230	ENGAGE in Wellness: Looking Inward	1
xx-xxx	Arts, Humanities and Social Sciences Course 3	9
		42

Reminder about Flexible Scheduling: Student feedback indicates that the junior year BS schedule can feel quite intense as you move into the more mathematical and physical chemistry oriented curriculum, especially if you are also engaged in undergraduate research. Remember that the senior year in chemistry is essentially open for free electives. You may use this flexibility to spread out your junior year requirements over four semesters rather than two. You should consult with your academic advisor to explore alternative schedules if you are interested.

Junior Year

Fall		Units
09-301	Undergraduate Seminar III	1
09-231	Mathematical Methods for Chemists Math methods is a co-requisite for 09-344 and a prerequisite for 09-345 (spring). If you move math methods to the fall of your senior year, you must also move 09-344, 09-345 and 09-322 to the senior year.	9
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry Quantum is a prerequisite for Lab IV. If you move Quantum to the fall of the senior year, you must move Lab IV to the spring of the senior year. 09-344 is not a prerequisite for 09-345 (spring).	9
09-323	Bioorganic Chemistry Laboratory This lab class is not a prerequisite for 09-322; it can be moved to the fall of your senior year without impacting the spring junior year courses.	12
38-330	ENGAGE in Wellness: Looking Outward	1
xx-xxx	Arts, Humanities and Social Sciences Course 4	9
		41

Spring		Units
09-302	Undergraduate Seminar IV	1
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV.	9
09-331	Modern Analytical Instrumentation This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV.	9
xx-xxx	Cultural/Global Understanding Requirement	9
xx-xxx	Approved Science and Society elective. This course can be scheduled at any point during your studies but prior to your final semester.	6-9
		46-49

Senior Year

Fall		Units
09-401	Undergraduate Seminar V	1
09-xxx	Biological Chemistry Elective 1 (see notes on electives)	9
09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates 09-718::or 09-719 will also fulfill this requirement.	9
or 09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	
38-110	ENGAGE in Service	1
38-430	ENGAGE in Wellness: Looking Forward	1
38-220	ENGAGE in the Arts	2
xx-xxx	Free Electives	21
		44

Spring		Units
09-402	Undergraduate Seminar VI	3
09-348	Inorganic Chemistry	10
xx-xxx	Biological Chemistry Elective 2	9
xx-xxx	Biological Chemistry Elective 3	9
xx-xxx	Free Electives	18
		49

Distribution of Units

Minimum Total Chemistry Units 187; See distribution below.

Required Chemistry Courses* Units		
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-219	Modern Organic Chemistry	10
09-220	Modern Organic Chemistry II	10
03-231	Honors Biochemistry	9
or 03-232	Biochemistry I	
09-231	Mathematical Methods for Chemists	9
09-331	Modern Analytical Instrumentation	9
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	9
or 09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	
09-348	Inorganic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-323	Bioorganic Chemistry Laboratory	12
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12
09-xxx	Chemistry Seminars	8
09-xxx	Biological Chemistry Electives	27

Students who transfer into the department and have taken 09-217 Organic Chemistry I and/or 09-218 Organic Chemistry II, will be required to complete units of 09-435 Independent Study Chemistry, 1 unit per course, under the supervision of the instructor(s) for 09-219 and/or 09-220 in order to master the course content missed in this course sequence.

Students who transfer into the department and have taken 09-207 Techniques in Quantitative Analysis and/or 09-208 Techniques for Organic Synthesis and Analysis will be required to take a 3 unit transition course (09-215 Chemistry Tech I to Lab I Transition for 09-207 and/or 09-216 Chemistry Tech II to Lab II Transition for 09-208) to fulfill the major requirements for 09-221 and/or 09-222.

Chemistry courses required for the BS degrees that are numbered 09-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances.

Other Requirements	**Units**
Modern Biology	**9**
Computer Science	**10**
Mathematics	**20**
Physics	**21**
Interpretation and Argument	**9**
Arts, Humanities and Social Sciences courses	**36**
Cultural/Global Understandling	**9**
EUREKA! (First Year Seminar)	**6**
Science and Society Elective	**6**

ENGAGE in Wellness (3 courses)	**3**
ENGAGE in Service	**1**
ENGAGE in the Arts	**2**
Core@CMU	**3**
Free Electives	**38**
Minimum number of units required for the degree:	**360**

The above B.S. curriculum recommends a range of 41–50 units/semester to meet the minimum degree requirement. Students are strongly encouraged to take extra elective courses (except in the first year) in whatever subjects they wish in order to enrich their backgrounds and enhance their educational experience.

Some students may need to earn more than 360 units to complete their degree. Usually this happens when students earn AP Credit for a course (for example 09-105) and then take a class with the same or similar content (take 09-105 at CMU or 09-107). You cannot count 20 units towards a 10-unit requirement so this student would need to earn 370 total units.

NOTES ON ELECTIVES

Biological Chemistry Electives

A minimum of three biological chemistry electives for a total of 27 units or more is required.

A list of currently approved electives is provided below. Of the three elective courses at least two should be chemistry courses and a maximum of one can be taken in biology or physics. Exceptions can be granted by the Director of Undergraduate Studies. One semester of 09-445 for 9 units may be used for one biological chemistry elective with the approval of the Director of Undergraduate Studies. It must be part of a longer term experience ensuring depth of knowledge in the area.

09-403	Hooked: The Chemical Basis of Drug Addiction	9
09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates (One of these two courses is required for the degree. The other can be used as a Biological Chemistry elective.)	9
or 09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	
09-521	Metals in Biology: Function and Reactivity	6
09-522	Kinetics and Mechanisms of Chemical and Enzymatic Reactions	9
09-530	Chemistry of Gene Expression	9
or 09-730	Chemistry of Gene Expression	
09-538	Exposure and Risk Assessment for Environmental Pollutants	9
09-621	Welcome to the Future Lab - Science in the Cloud Must be taken with 09-623	6
09-623	Future Lab- DNA Science in the Cloud	6
09-737	Medicinal Chemistry and Drug Development	12
09-738	Exposure and Risk Assessment for Environmental Pollutants	12
03-220	Genetics	9
03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	9
03-320	Cell Biology	9
03-344	Experimental Biochemistry	12
03-362	Cellular Neuroscience	9
03-366	Neuropharmacology: Drugs, Brain and Behavior	9
03-390	Molecular and Cellular Immunology	9
03-391	Microbiology	9
03-435	Cancer Biology	9
03-439	Introduction to Biophysics	10
03-442	Molecular Biology	9
03-729	Entrepreneurship and protein-based drug development	6
03-740	Advanced Biochemistry	12
03-871	Structural Biophysics	12
33-441	Introduction to Biophysics	10

Free Electives

Free electives are defined as including any course offered by Carnegie Mellon except those in science or engineering fields that are primarily intended for non-majors. A maximum of 9 units total of Physical Education, StuCo and/or ROTC courses combined can be counted as free elective units. The Chemistry Department does not require technical electives.

Options for the Bachelor's Degrees in Chemistry

The curriculum for the degree Bachelor of Science in Chemistry permits students to take a number of elective courses in chemistry and other fields, particularly in the junior and senior years. Students may wish to complete a group of elective courses from several specialty areas, called “options,” to complement their technical education. Each option will complement the Bachelor's degree in Chemistry and will provide students with expertise in a specific area not covered by the normal undergraduate curriculum. Options are noted on the student's transcript but not on the diploma.

For each of the following options, the student should refer to the previous description of the curriculum for the B.S.or B.A. degrees in chemistry. Required courses are unchanged, and the courses that should be taken as electives for each option are listed below. Chemistry courses within an option also count towards fulfillment of the chemistry elective requirement for the B.S. degree. The courses can fulfill MCS technical core requirements (and in some cases non-technical core requirements i.e the management option) but there is very limited ability to count a course for an option and also for a minor or additional major/degree in a related area. You will need to consult with the appropriate advisors about double counting issues.

A student who completes the recommended courses for any of these options will receive a certificate from the Department of Chemistry at Commencement as formal evidence of the accomplishment and a notation of this will be made on the student's transcript.

BIOCHEMISTRY OPTION		Units
03-231/232	Honors Biochemistry (or Biochemistry)	9
09-518/718	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	9
or 09-718	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	
or 09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	
or 09-719	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	
xx-xxx	2 Electives in Biochemistry	
Elective courses may be chosen from the following list. (Other courses listed as electives for the Biological Chemistry Track may be possible with permission.)		
03-344	Experimental Biochemistry	12
09-445	Undergraduate Research 9 units of 09-445 can count towards this option if part of a longer term immersion in a relevant area and approved by the Director of Underraduate Studies	Var.
09-530	Chemistry of Gene Expression	9
or 09-730	Chemistry of Gene Expression	
09-737	Medicinal Chemistry and Drug Development	12
03-439	Introduction to Biophysics	10
09-519/719	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	9
or 09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	
or 09-718	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	
03-740	Advanced Biochemistry	12

POLYMER SCIENCE OPTION		Units
09-502/741	Organic Chemistry of Polymers	9
09-760	The Molecular Basis of Polymer Mechanics	12
Two Electives in Polymer Science		9
Elective courses may be chosen from the following list		
09-445	Undergraduate Research 9 units of 09-445 can count towards this option if part of a longer term immersion in a relevant area and approved by the Director of Undergraduate Studies	9
09-509/715	Physical Chemistry of Macromolecules	9
09-736	Transition Metal Catalysis for Organic and Polymer Synthesis	12
27-477	Introduction to Polymer Science and Engineering	9

Other upper level courses in chemistry, biomedical engineering, materials science engineering or the colloids, polymers and surfaces program may be used with permission of the Director of Undergraduate Studies

MATERIALS CHEMISTRY OPTION		Units
27-100	Engineering the Materials of the Future	12
27-201	Structure of Materials	9
Two Elective Courses of at least 9 units each from the list below		
27-202	Defects in Materials	9
09-445	Undergraduate Research 9 units of 09-445 can count towards this option if part of a longer term immersion in a relevant area and approved by the Director of Undergraduate Studies	9
09-502/741	Organic Chemistry of Polymers	9
09-507/707	Nanoparticles	9
09-509/715	Physical Chemistry of Macromolecules	9
09-723	Proximal Probe Techniques: New Tools for Nanoscience & Nanotechnology	12
27-xxx	MSE course approved by Director of Undergraduate Studies	

ENVIRONMENTAL CHEMISTRY OPTION		Units
09-510/710	Chemistry and Sustainability	9
or 09-381	Environmental Systems on a Changing Planet	
09-524	Environmental Chemistry	9
or 09-724	Environmental Chemistry	
Two elective courses of at least 9 units each from the list below		
09-445	Undergraduate Research 9 units of 09-445 can count towards this option if part of a longer term immersion in a relevant area and approved by the Director of Undergraduate Studies	Var.
09-225	Climate Change: Chemistry, Physics and Planetary Science	9
09-529/729	Introduction to Sustainable Energy Science	9
09-538/738	Exposure and Risk Assessment for Environmental Pollutants	9
19-440	Combustion and Air Pollution Control	9
12-651	Air Quality Engineering	9
12-657	Water Resource Systems Engineering	9
12-702	Fundamentals of Water Quality Engineering	12

MANAGEMENT OPTION		Units
70-100	Global Business Global Business is intended for first-year and sophomore students only. Juniors and seniors interested in pursuing the management option must replace the course with a constrained elective as defined for the Minor in Business Administration.	9
73-102	Principles of Microeconomics	9
70-122	Introduction to Accounting	9
Tepper Constrained Elective: As defined in the 2024-25 Undergraduate Catalog these must be one of the following courses: 70-311, 70-371, 70-381, or 70-391		9

COMPUTATIONAL CHEMISTRY OPTION		Units
15-112	Fundamentals of Programming and Computer Science	12
15-122	Principles of Imperative Computation	12
or 15-150	Principles of Functional Programming	
21-127	Concepts of Mathematics	12
09-563/763	Molecular Modeling and Computational Chemistry	9
xx-xxx	One Upper Level Computational Elective Course of at least 9 units from the list below	
09-615	Computational Modeling, Statistical Analysis and Machine Learning in Science	12
09-621	Welcome to the Future Lab - Science in the Cloud Must be taken with 09-623	6
15-210	Parallel and Sequential Data Structures and Algorithms	12
15-213	Introduction to Computer Systems	12
15-214	Principles of Software Construction: Objects, Design, and Concurrency	12
33-241	Introduction to Computational Physics	9
02-250	Introduction to Computational Biology	12

B.S. in Chemistry with Departmental Honors

Outstanding students with an interest in research are encouraged to consider the Honors program by the beginning of the junior year. The program combines a slightly modified B.S. curriculum with close faculty-student contact in an individual research project, concluding with the student's presentation and defense of a Bachelor's degree honors thesis to a Thesis Committee.

The B.S. in Chemistry with Departmental Honors curriculum follows the general sequence of courses that is listed for the B.S. degree. The honors program specifies that one of the two **chemistry** electives be a 12-unit graduate course, numbered 09-7xx or higher, and that of the remaining free electives required to reach the minimum 360 units for the degree, at least two be undergraduate research (totaling at least 18 units) and one be 09-455 Honors Thesis (taken for 6 units). Students will be encouraged to do more than the minimum amount of research, so stipends from the research advisor or other sources such as a Summer Undergraduate Research Fellowship are sometimes available for summer B.S. honors research.

By the end of the penultimate semester, candidates for the B.S. in chemistry may apply to be admitted for candidacy to the Honors B.S. program. Applications are available on the department Canvas site for chemistry majors. To be accepted, students will be expected to have shown excellent performance in class work – normally at least a 3.2 average QPA- and outstanding progress in undergraduate research. A statement of support from their research advisor is also required. Upon acceptance into the program, a Thesis Committee must be identified, which will monitor the progress of the student. The committee shall consist of at least one member of the Undergraduate Program Committee to be appointed by the Director of Undergraduate Studies, the student's research advisor and a third faculty member agreed upon by the student and advisor. This third member can be from another department or institution and can be tenure track, teaching track or research track faculty. It is the student's responsibility to contact the proposed third member of their committee and confirm their participation.

A Box folder will be created for each degree candidate. Information relevant to their candidacy that includes for example the completed application and written work products including documents and slides should be uploaded to this folder. The folder will be accessible to the student, members of the Undergraduate Program Committee and the student's thesis committee.

A written thesis suitable for an Honors B.S. degree is required and should be a clear exposition in proper scientific format of a research project done for at least 18 units of credit in 09-445 Undergraduate Research. The thesis should describe a substantive new contribution to a particular field of research. This could include, but is not limited to, the discovery of a new phenomenon, studies that enhance our understanding of a previously reported phenomenon, or the development of a new method or technique. The student's Thesis Committee will evaluate the thesis via a public oral presentation followed by a private defense of the thesis before it approves the Honors degree. The written thesis must be supplied to the members of the student's Thesis Committee no later than 1 week prior to the scheduled public defense. The defense is usually scheduled to take place during April or early May of the senior year (for a May graduation date but will change accordingly fo an August or December graduation) and the Director of Undergraduate Studies will coordinate the selection of a suitable date. Students completing the B.S. with Departmental Honors in Chemistry will receive MCS College Honors as well.

The designations of MCS College Honors and Departmental Honors are noted on the transcript but not on the diploma. Only University Honors are noted on the diploma.

Honors B.S. - M.S. Program in Chemistry

Overview

Outstanding students seeking an advanced degree are encouraged to apply for admission to the B.S./M.S. Honors program as early as they can but only after having made some progress on a research project that could eventually be suitable for production of a Master's level thesis. Please note that this degree is available only with the B.S. in chemistry or the B.S. in Chemistry/Biological Chemistry Track and cannot be obtained by students pursuing a B.A. degree in chemistry. Typically, applications are submitted during the second half of the sophomore year but no later than the first semester of the junior year. (Later applications would only be considered in exceptional circumstances and would generally involve staying for a fifth year of study.) Participants will have the opportunity to earn in four years not only the degree B.S. in Chemistry with Departmental Honors, but also the degree Master of Science in Chemistry. This program is highly research intensive and is not appropriate for all students. Requirements include completing five graduate level courses as electives. (See notes on Honors B.S./M.S. electives.)

The schedule of courses for the B.S./M.S. program generally moves as many courses as possible forward in the curriculum, though this is not a requirement. This gives the student the following advantages: 1) greater perspective in selection of a research advisor, 2) greater maturity in performing independent research, and 3) the possibility of initiating the graduate course sequence in the junior year.

Application Process

A completed application, finished in collaboration with their thesis advisor, must be submitted to the Director of Undergraduate Studies who will then arrange for an application meeting with the student, research advisor and representatives of the department Undergraduate Program Committee. (The application is available on the Canvas site for undergraduate chemistry majors.) At this meeting the student is expected to give an oral presentation with visual aids that presents relevant background, a summary of work completed to date and a detailed plan for their thesis project including a projected timeline for completion of the thesis research and the thesis itself. The presentation generally lasts around 15 minutes. The committee may have questions for the candidate and/or advisor .

Thesis Committee

Upon acceptance into the program, a Thesis Committee must be identified, which will monitor the progress of the student. The Director of Undergraduate Studies generally initiates this process. The committee shall consist of at least one member of the Undergraduate Program Committee appointed by the Director of Undergraduate Studies, the student's research advisor and a third faculty member agreed upon by the student and advisor. This third member can be from another department or institution and can be tenure track, teaching track or research track faculty. It is the student's responsibility to contact the third member of their committee, confirm their participation and notify the Director of Undergraduate Studies.

A Box folder will be created for each degree candidate. Information relevant to their candidacy that includes for example the completed application and written work products including documents and slides should be uploaded to this folder. The folder will be accessible to the student, members of the Undergraduate Program Committee and the student's thesis committee.

Research Engagement

The student is expected to keep the research advisor selected for the duration of the thesis project. Summer thesis research for 10 weeks in each summer following the sophomore and junior years is strongly suggested to assist the student in completing research of sufficient quantity and quality to complete their thesis. Students normally will be given stipends for their summer work either by their research advisor or by competing for a summer fellowship such as a Summer Undergraduate Research Fellowship available through the Undergraduate Research Office. A minimum of 30 units of 09-445 Undergraduate Research is required though this is rarely sufficient as the sole research experience. Participation in group seminars during the junior and senior years is expected. Students must present their research at least once at the Sigma Xi competition at Meeting of the Minds, the annual Carnegie Mellon undergraduate research symposium, typically at the end of the junior year. In addition, students must meet with their Thesis Committee at minimum each fall, though additional meetings may be required by the Thesis Committee, to update the committee on their progress and in the fall of the senior year must prepare a written summary of their research progress to date (5 pages) and their plans for the academic year (1 page). This report must state clearly what stage the work is in; it must be clear what work is complete and ready for publication.

Failure to maintain what the committee deems as suitable progress towards degree in either research or graduate coursework may result in release from the program. The final decision rests with the Director of Undergraduate Studies in consultation with the thesis committee.

A meeting with the thesis committee should occur during the first two weeks of the final semester. The purpose of this meeting is to determine whether the candidate has made sufficient progress in research to warrant the production of a suitably rigorous thesis towards an M.S. degree according to the planned upon schedule. If the student has not made appropriate progress, they may have the option of extending their time to degree or pursuing Departmental Honors through writing and defense of a senior honors thesis as described elsewhere in this catalog.

Preparation for Writing the Thesis and the Thesis Defense

By the end of the penultimate semester (normally fall of the senior year) the student should complete a thorough literature review to begin preparation for the introduction of their thesis.

At the start of the spring semester of the senior year (or their final semester if different), the student must submit a draft of the introduction for their thesis and a detailed outline of their methods, results and discussion sections to the Director of Undergraduate Studies who also chairs the Honors Committee. This will be distributed via Box and reviewed by the student's Thesis Committee.

Each student is required to submit a formal Masters Degree dissertation to the Chemistry Department in April of the senior year (for a May graduation date) or at least one week prior to the date set for the thesis defense. The thesis usually has an abstract, introduction, methods, results, discussion and conclusion sections with acknowledgements. It is common for a Masters dissertations to contain multiple chapters describing various aspects of the project. The student's Thesis Committee will evaluate the thesis via a public oral presentation followed by a private defense of the thesis before the Thesis Committee. The defense is usually scheduled to take place during April or early May of the senior year and the Director of Undergraduate Studies will coordinate the selection of a suitable date. The defense presentation generally lasts around 30-40 minutes.

The dissertation, written in proper scientific format, should describe the research project in considerable detail and must withstand the scrutiny of the Thesis Committee with respect to completeness. It need not be as extensive nor contain the element of student originality characteristic of a Ph.D. thesis; however it must contain results and conclusions that are of a high enough quality to be accepted as a publication in a respected research journal, though publication of the work is not a requirement of the degree program. The student should refer to the ACS Style Guide for recommendations on appropriate presentation and formatting of written text, tables, graphs, and figures. As for all M.S. degree candidates in the Department, the dissertation must be approved first by the research advisor before it can be distributed to the rest of the committee. Thus, it is essential to give the complete thesis or individual chapters to the advisor for feedback well before the one-week deadline for submission to the full committee.

Research productivity is the most important criterion for success at the evaluation points, but QPA is a strong secondary criterion. A minimum of 3.2 and strong progress in research are required to remain in the program. Candidates must also maintain a QPA of at least 3.0 in the five graduate level courses required for the degree.

Students who complete this program will receive the designations of Departmental Honors and MCS College Honors. These are designated on the transcript, not on the diploma. Only University Honors are denoted on the diploma.

Students completing the requirements for this degree receive two diplomas, one for the B.S. degree and another for the M.S. degree. Since this is a combined degree program both degrees are awarded at the same time; the awarding of the two degrees cannot be separated in time. It is not uncommon for students to extend their time to degree through the summer following their planned May graduation in order to finish writing and defense of their M.S. thesis. There students are able to walk with their graduating class in May, though they will not receive their diplomas until after their thesis defense and submission of their grade for 09-455.

Failure to make progress in research or coursework of sufficient quality and quantity in a timely fashion can result in a student being removed from this degree program (removal of the M.S. degree from their record). The decision will be made by the thesis committee and the Director of Undergraduate Studies. Violations of professional ethical standards can also result in a student's removal from the B.S.-M.S. program. This will not interfere with the student earning a B.S. degree, the BS with the Biological Chemistry Track or the B.S. degree with Departmental Honors, provided the appropriate requirements are met.

Notes on Honors B.S. - M.S. Graduate Level Electives

The B.S. - M.S. Honors degree requires the completion of five graduate level courses. Graduate courses in chemistry are typically those numbered 09-7xx or 09-8xx. Some courses numbered 09-6xx are remedial graduate level courses and not acceptable towards the degree requirements as the content overlaps extensively with required chemistry courses at the undergraduate level (an example is 09-611 Chemical Thermodynamics). Others are part of established M.S programs in the college and may be possible candidates for fulfillment of this requirement (examples being 09-615 Computational Modeling, Statistical Analysis and Machine Learning in Science, 09-616 Neural Networks & Deep Learning in Science and 09-621 Welcome to the Future Lab - Science in the Cloud that must be taken with 09-623 Future Lab- DNA Science in the Cloud). Graduate classes in chemistry are normally 12-unit courses (or two six unit minis numbered

09-7xx or 09-8xx counting as one graduate level course). However, in order not to penalize interdisciplinary studies which may be essential to a good thesis, up to three of the five required graduate chemistry courses may be at the advanced undergraduate level (the 9 unit 09-5xx versions), though the 09-7xx course is generally preferred as the additional 3-units of work often target work or skills important to graduate-level work. All advanced undergraduate level courses used to satisfy this requirement must be approved by the Director of Undergraduate Studies. Students must earn a grade of C or better in each of the five graduate or upper level undergraduate courses fulfilling the requirements for this degree and also in 09-455, Honors Thesis. In addition students must earn a minimum of a 3.0 average combined for the five graduate or upper level undergraduate courses, 09-445 Undergraduate Research and 09-455 Honors Thesis in order to fulfill their degree requirements.

Curriculum for Students Pursuing the Honors B.S. - M.S. in Chemistry

This catalog and the sample schedules presented are intended to be used by students in the first year class entering in the fall of 2024. Upperclass students should refer to the appropriate previous version of the catalog published during their first year for the requirements that are specific to them.

The non-technical breadth requirements for MCS students includes Interpretation and Argument (76-101, 9 units), four courses with a minimum of 36 units from the arts, humanities or social sciences and a course of at least 9 units from an approved list in the category of Cultural/Global understanding, a course in the Science and Society category of at least 6 units, a total of five ENGAGE courses including three ENGAGE in Wellness courses, ENGAGE in Wellness: Looking Inward (38-230, 1 units), ENGAGE in Wellness: Looking Outward (38-330, 1 units) and ENGAGE in Wellness: Looking Forward (38-430, 1 units), as well as ENGAGE in Service (38-110, 1 units) and ENGAGE in the Arts (38-220, 2 units) plus EUREKA!: Discovery and Its Impact (38-101, 6 units) the MCS first-year seminar and 99-101 Core@CMU, for a minimum of 75 units.

The Science and Society requirement as well as the ENGAGE courses must be finished **prior** to your final semester at CMU (no later than your penultimate semester). The Science and Society requirement can be fulfilled in numerous ways via MCS classes and other disciplinary courses that can also fulfill other requirements for your degree (but can NOT double count within the general education categories i.e. a course used to fulfill Science and Society cannot also fulfill your Cultural Analysis requirement or count towards your 36 units of non-technical electives). In the chemistry department courses currently approved to fulfill the Science and Society requirement that can also count as a chemistry elective are 09-510 Chemistry and Sustainability (or the graduate version,09-710), 09-381 Environmental Systems on a Changing Planet and 09-403 Hooked: The Chemical Basis of Drug Addiction. A more expanded listing will be maintained by the MCS Dean's Office (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/index.html (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/)).

The Science and Society requirement as well as the ENGAGE courses must be finished **prior** to your final semester at CMU (no later than your penultimate semester). The Science and Society requirement can be fulfilled in numerous ways via MCS classes and other disciplinary courses that can also fulfill other requirements for your degree (but can NOT double count within the general education categories i.e. a course used to fulfill Science and Society cannot also fulfill your Cultural Analysis requirement or count towards your 36 units of non-technical electives). In the chemistry department courses currently approved to fulfill the Science and Society requirement that can also count as a chemistry elective are 09-510 Chemistry and Sustainability , 09-381 Environmental Systems on a Changing Planetand 09-403 Hooked: The Chemical Basis of Drug Addiction. A more expanded listing will be maintained by the MCS Dean's Office (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/index.html (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/)).

For more information on allowed courses in the arts, humanities and social sciences and electives in the Cultural/Global Understanding category refer to the MCS section of this catalog.

The suggested curriculum recommends that the required technical courses be completed at the earliest opportunity, however students have considerable flexibility to postpone these courses in favor of electives, allowing compatibility with the programs of other departments. In designing such programs for a minor or additional major with chemistry, students should note that certain required chemistry courses only are offered in specific semesters, not both. These include the Fall-only courses , 09-219 Modern Organic Chemistry, 09-321 Laboratory III: Molecular Design and Synthesis and 09-323 Bioorganic Chemistry Laboratory and 09-344 Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry as well as the Spring-only courses 09-331 Modern Analytical Instrumentation, 09-220 Modern Organic Chemistry II, 09-345 Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry and 09-348 Inorganic Chemistry. Also, in some cases, a course that is normally scheduled for the fall may be changed to a spring course (or the inverse) due to a departmental curriculum change or faculty availability.

The following are only meant to represent sample schedules. Students should always consult with their academic advisor to discuss an individualized plan to meet their academic goals.

Fall		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
21-120	Differential and Integral Calculus	10
33-121	Physics I for Science Students	12
38-101	EUREKA!: Discovery and Its Impact	6
76-101	Interpretation and Argument	9
99-101	Core@CMU	3
		50

Students interested in majoring in chemistry who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

There are some elective laboratory courses offered for MCS students in the first year. These include 03-117 Frontiers, Analysis, and Discovery in Biological Sciences and 09-115 Introduction to Undergraduate Research in Chemistry., which can serve as the prerequisite for the research shadowing course 09-116 Undergraduate Research Shadowing in Chemistry in the spring semester. The maximum units allowed during the first semester is 54; therefore, students wishing to take a lab should take an alternate technical course to Physics I such as 15-110 or 03-121 so that their unit total is lower.

Spring		Units
09-106	Modern Chemistry II Chemistry majors who place out of 09-106 can take 09-348 Inorganic Chemistry, 09-510 Chemistry and Sustainability as a chemistry elective or inquire with the Director of Undergraduate Studies about a suitable research placement.	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	
15-110	Principles of Computing	10
or 33-121	Physics I for Science Students	
or 03-121	Modern Biology	
xx-xxx	Arts, Humanities and Social Sciences Course 1	9
xx-xxx	Free Elective	9
		48

Sophomore Year

Fall		Units
09-219	Modern Organic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-201	Undergraduate Seminar I	1
33-122	Physics II for Biological Sciences & Chemistry Students This course is a prerequisite for 09-331, normally taken in the spring of the junior year.	9
09-445	Undergraduate Research	9
xx-xxx	Arts, Humanities and Social Sciences Course 2	9
		50

Spring		Units
09-202	Undergraduate Seminar II: Safety and Environmental Issues for Chemists	1
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-220	Modern Organic Chemistry II	10
09-348	Inorganic Chemistry	10
38-230	ENGAGE in Wellness: Looking Inward	1

xx-xxx	Arts, Humanities and Social Sciences Course 3	9
		43

Summer

10 weeks Honors Research recommended

Reminder about Flexible Scheduling: Student feedback indicates that the junior year BS schedule can feel quite intense as you move into the more mathematical and physical chemistry oriented curriculum, especially if you are also engaged in undergraduate research. Remember that the senior year in chemistry is essentially open for free electives. You may use this flexibility to spread out your junior year requirements over four semesters rather than two. You should consult with your academic advisor to explore alternative schedules if you are interested.

Junior Year

Fall		Units
09-301	Undergraduate Seminar III	1
09-231	Mathematical Methods for Chemists	9
09-321	Laboratory III: Molecular Design and Synthesis	12
or 09-323	Bioorganic Chemistry Laboratory	
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-445	Undergraduate Research	9
38-330	ENGAGE in Wellness: Looking Outward	1
xx-xxx	Arts, Humanities and Social Sciences Course 4	9
		50

Spring		Units
09-302	Undergraduate Seminar IV	1
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12
09-445	Undergraduate Research	6
09-xxx	Graduate Chemistry Course 1 of 5 (see notes on Honors B.S. - M.S. electives in the generalized program description)	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-331	Modern Analytical Instrumentation	9
xx-xxx	Approved Science and Society elective. This course can be scheduled at any point during your studies but prior to your final semester.	6-9
		52-55

Summer

10 weeks Honors Research recommended

Senior Year

Fall		Units
09-401	Undergraduate Seminar V	1
09-445	Undergraduate Research	9
09-xxx	Graduate Chemistry Course 2 of 5	12
09-xxx	Graduate Chemistry Course 3 of 5	12
xx-xxx	Cultural/Global Understanding	9
38-430	ENGAGE in Wellness: Looking Forward	1
38-110	ENGAGE in Service	1
		45

Spring		Units
09-402	Undergraduate Seminar VI	3
09-455	Honors Thesis	15
09-xxx	Graduate Chemistry Course 4 of 5	9
09-xxx	Graduate Chemistry Course 5 of 5	9
38-220	ENGAGE in the Arts	2
xx-xxx	Free Elective	9
		47

Distribution of Units

Minimum Total Chemistry Units (238, See distribution below)

Required Chemistry Courses		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-219	Modern Organic Chemistry	10
09-220	Modern Organic Chemistry II	10
09-231	Mathematical Methods for Chemists	9
09-331	Modern Analytical Instrumentation	9
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-348	Inorganic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-321	Laboratory III: Molecular Design and Synthesis	12
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12
09-xxx	Chemistry Seminars	8
09-445	Undergraduate Research (in addition 2 summers recommended)	30
09-xxx	Graduate chemistry courses (see Notes on B.S./ M.S. Electives)	51-60
09-455	Honors Thesis	15

Students who transfer into the department and have taken 09-217 Organic Chemistry I, and/or 09-218 Organic Chemistry II, will be required to complete units of 09-435 Independent Study Chemistry, 1 unit per course, under the supervision of the instructor(s) for 09-219 and/or 09-220 in order to master the course content missed in this course sequence.

Students who transfer into the department and have taken 09-207 Techniques in Quantitative Analysis and/or 09-208 Techniques for Organic Synthesis and Analysis will be required to take a 3 unit transition course (09-215 Chemistry Tech I to Lab I Transition for 09-207 and/or 09-216 Chemistry Tech II to Lab II Transition for 09-208) to fulfill the major requirements for 09-221 and/or 09-222.

Chemistry courses required for the B.S. - M.S. degree that are numbered 09-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances.

Other Requirements	**Units**
Biology	**9**
Computer Science	**10**
Mathematics	**20**
Physics	**21**
Interpretation and Argument	**9**
Arts, Humanities and Social Sciences courses	**36**
Cultural/Global Understanding	**9**
EUREKA! (first year seminar)	**6**
Science and Society Elective	**6**
ENGAGE in Wellness (3 courses)	**3**
ENGAGE in Service	**1**
ENGAGE in the Arts	**2**
Core@CMU	**3**
Free Electives	**6-15**
Minimum number of units required for degrees:	**388**

The above B.S. curriculum recommends a range of 41–55 units per semester to meet the minimum degree requirement of 388 units. Students are strongly encouraged to take extra elective courses (except in the first year) in whatever subjects they wish in order to enrich their backgrounds and enhance their educational experience.

Some students may need to earn more than 388 units to complete their degree. Usually this happens when students earn AP Credit for a course (for example 09-105) and then take a class with the same or similar content (take 09-105 at CMU or 09-107). You cannot count 20 units towards a 10-unit requirement so this student would need to earn 398 total units.

Free Electives

Free electives are defined as including any course offered by Carnegie Mellon except those in science or engineering fields that are primarily intended for non-majors. A maximum of 9 units total of Physical Education, StuCo and/or ROTC courses combined can be counted as free elective units. The Chemistry Department does not require technical electives.

Curriculum for Students Pursuing the B.S. in Chemistry/ Biological Chemistry Track-M.S. Degree in Chemistry

This catalog and the sample schedules presented are intended to be used by students in the first year class entering in the fall of 2024. Upperclass students should refer to the appropriate previous version of the catalog published during their first year for the requirements that are specific to them.

The non-technical breadth requirements for MCS students includes Interpretation and Argument (76-101, 9 units), four courses with a minimum of 36 units from the arts, humanities or social sciences and a course of at least 9 units from an approved list in the category of Cultural/Global understanding, a course in the Science and Society category of at least 6 units, a total of five ENGAGE courses including three ENGAGE in Wellness courses, ENGAGE in Wellness: Looking Inward (38-230, 1 units), ENGAGE in Wellness: Looking Outward (38-330, 1 units) and ENGAGE in Wellness: Looking Forward (38-430, 1 units), as well as ENGAGE in Service (38-110, 1 units) and ENGAGE in the Arts (38-220, 2 units) plus EUREKA!: Discovery and Its Impact (38-101, 6 units) the MCS first-year seminar and 99-101 Core@CMU, for a minimum of 75 units.

The Science and Society requirement as well as the ENGAGE courses must be finished **prior** to your final semester at CMU (no later than your penultimate semester). The Science and Society requirement can be fulfilled in numerous ways via MCS classes and other disciplinary courses that can also fulfill other requirements for your degree (but can NOT double count within the general education categories i.e. a course used to fulfill Science and Society cannot also fulfill your Cultural Analysis requirement or count towards your 36 units of non-technical electives). In the chemistry department courses currently approved to fulfill the Science and Society requirement that can also count as a chemistry elective are 09-510 Chemistry and Sustainability (or the graduate version,09-710), 09-381 Environmental Systems on a Changing Planet and 09-403 Hooked: The Chemical Basis of Drug Addiction. A more expanded listing will be maintained by the MCS Dean's Office (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/index.html (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/)).

For more information on allowed courses in the arts, humanities and social sciences and electives in the Cultural/Global Understanding category refer to the MCS section of this catalog.

The suggested curriculum recommends that the required technical courses be completed at the earliest opportunity, however students have considerable flexibility to postpone these courses in favor of electives, allowing compatibility with the programs of other departments. In designing such programs for a minor or additional major with chemistry, students should note that certain required chemistry courses only are offered in specific semesters, not both. These include the Fall-only courses , 09-219 Modern Organic Chemistry, 09-321 Laboratory III: Molecular Design and Synthesis and 09-323 Bioorganic Chemistry Laboratory and 09-344 Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry as well as the Spring-only courses 09-331 Modern Analytical Instrumentation, 09-220 Modern Organic Chemistry II, 09-345 Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry and 09-348 Inorganic Chemistry. Also, in some cases, a course that is normally scheduled for the fall may be changed to a spring course (or the inverse) due to a departmental curriculum change or faculty availability.

The following are only meant to represent sample schedules. Students should always consult with their academic advisor to discuss an individualized plan to meet their academic goals.

Freshman Year

Fall		Units
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
21-120	Differential and Integral Calculus	10
33-121	Physics I for Science Students	12
or 03-121	Modern Biology	
76-101	Interpretation and Argument	9
38-101	EUREKA!: Discovery and Its Impact	6
99-101	Core@CMU	3
		50

Students interested in majoring in chemistry who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

There are some elective laboratory courses offered for MCS students in the first year. These include 03-117 Frontiers, Analysis, and Discovery in Biological Sciences or 09-115 Introduction to Undergraduate Research in Chemistry. The maximum units allowed during the first semester is 54; therefore, students wishing to take a lab should take an alternate technical course to Physics I such as 15-110 or 03-121 so that their unit total is lower.

Spring		Units
09-106	Modern Chemistry II *	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	
03-121	Modern Biology	9
or 33-121	Physics I for Science Students	
or 15-110	Principles of Computing	
xx-xxx	Arts, Humanities and Social Sciences Course 1	9
xx-xxx	Free Elective	5
		43

* Chemistry majors who place out of 09-106 can take 09-348 Inorganic Chemistry, 09-510 Chemistry and Sustainability as a chemistry elective, or other courses yet to be announced. Chemistry majors who feel they are ready for an undergraduate research experience should meet with the Director of Undergraduate Studies. These opportunities are more prevalent in the summer after your first year or sophomore year.

Sophomore Year

Fall		Units
09-201	Undergraduate Seminar I	1
09-219	Modern Organic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
33-122	Physics II for Biological Sciences & Chemistry Students Course is a prerequisite for 09-331, normally taken in the spring of the junior year. This ourse can be delayed until a subsequent semester in order to better manage workload.	9
03-220	Genetics or other biological chemistry elective.	9
xx-xxx	Arts, Humanities and Social Sciences Course 2	9
		50

Spring		Units
09-202	Undergraduate Seminar II: Safety and Environmental Issues for Chemists	1
09-220	Modern Organic Chemistry II	10
09-222	Laboratory II: Organic Synthesis and Analysis	12
03-232	Biochemistry I	9
38-230	ENGAGE in Wellness: Looking Inward	1
xx-xxx	Arts, Humanities and Social Sciences Course 3	9
		42

Summer Research: 10 weeks of summer research is recommended

Reminder about Flexible Scheduling: Student feedback indicates that the junior year BS schedule can feel quite intense as you move into the more mathematical and physical chemistry oriented curriculum, especially if you are also engaged in undergraduate research. Remember that the senior year in chemistry is essentially open for free electives. You may use this flexibility to spread out your junior year requirements over four semesters rather than two. You should consult with your academic advisor to explore alternative schedules if you are interested.

Junior Year

Fall		Units
09-301	Undergraduate Seminar III	1
09-231	Mathematical Methods for Chemists Math methods is a co-requisite for 09-344 and a prerequisite for 09-345 (spring). If you move math methods to the fall of your senior year, you must also move 09-344, 09-345 and 09-322 to the senior year.	9
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry Quantum is a prerequisite for Lab IV. If you move Quantum to the fall of the senior year, you must move Lab IV to the spring of the senior year. 09-344 is not a prerequisite for 09-345 (spring).	9
09-323	Bioorganic Chemistry Laboratory This lab class is not a prerequisite for 09-322; it can be moved to the fall of your senior year without impacting the spring junior year courses.	12
09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates One course from the set 09-518, 718, 519, 719 is required for the track.	9
38-330	ENGAGE in Wellness: Looking Outward	1
xx-xxx	Arts, Humanities and Social Sciences Course 4	9
		50

Spring		Units
09-302	Undergraduate Seminar IV	1
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV.	9
09-331	Modern Analytical Instrumentation This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV.	9
xx-xxx	Cultural/Global Understanding Requirement	9
xx-xxx	Track Elective #2 (if you choose a class at the 09-5xx, 7xx or 8xx level it can double count for the track and the graduate classes for the MS degree.**)	
xx-xxx	Approved Science and Society elective. This course can be scheduled at any point during your studies but prior to your final semester.	6-9
		46-49

** Double counting: One of the required bioorganic courses and an appropriate, upper level undergraduate or graduate level chemistry class can double count towards the three track electives and the five required graduate courses for the MS degree. This is reflected in this schedule.

Summer Research:10 weeks of summer research is recommended

Senior Year

Fall		Units
09-401	Undergraduate Seminar V	1
09-xxx	Biological Chemistry Elective 3 (see notes on Biological Chemistry electives)	9
xx-xxx	Graduate Course 1 (see notes in general description of BS-MS degrees)	9-12
xx-xxx	Graduate Course 2	9-12
38-110	ENGAGE in Service	1
38-430	ENGAGE in Wellness: Looking Forward	1
38-220	ENGAGE in the Arts	2
xx-xxx	Free Electives	16-23
		48-61

Spring		Units
09-402	Undergraduate Seminar VI	3
09-348	Inorganic Chemistry	10
xx-xxx	Graduate Course 3	9-12
09-455	Honors Thesis	15
xx-xxx	Free Electives	9
		46-49

DISTRIBUTION OF UNITS

Minimum Total Chemistry Units 271; See distribution below

Required Chemistry Courses* Units		
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
09-219	Modern Organic Chemistry	10
09-220	Modern Organic Chemistry II	10
03-231	Honors Biochemistry	9
or 03-232	Biochemistry I	
09-231	Mathematical Methods for Chemists	9
09-331	Modern Analytical Instrumentation	9
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates either 09-718 or 09-719 can also fulfill this requirement	9
or 09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	
09-348	Inorganic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-323	Bioorganic Chemistry Laboratory	12
09-322	Laboratory IV: Molecular Spectroscopy and Dynamics	12

09-xxx	Chemistry Seminars	8
09-xxx	Biological Chemistry Electives	27
09-445	Undergraduate Research	30
09-455	Honors Thesis	15
09-5xx/7xx graduate classes for the MS (3-4 required depending upon double counting)		27-48

Students who transfer into the department and have taken 09-217 Organic Chemistry I and/or 09-218 Organic Chemistry II, will be required to complete units of 09-435 Independent Study Chemistry, 1 unit per course, under the supervision of the instructor(s) for 09-219 and/or 09-220 in order to master the course content missed in this course sequence.

Students who transfer into the department and have taken 09-207 Techniques in Quantitative Analysis and/or 09-208 Techniques for Organic Synthesis and Analysis will be required to take a 3 unit transition course (09-215 Chemistry Tech I to Lab I Transition for 09-207 and/or 09-216 Chemistry Tech II to Lab II Transition for 09-208) to fulfill the major requirements for 09-221 and/or 09-222.

Chemistry courses required for the B.S. degrees that are numbered 09-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances.

**** Double counting: A maximum of one of the required bioorganic courses and an appropriate, upper level undergraduate or graduate level chemistry class can double count towards the three track electives and the five required graduate courses for the MS degree.**

Other Requirements	Units
Modern Biology	**9**
Computer Science	**10**
Mathematics	**20**
Physics	**21**
Interpretation and Argument	**9**
Arts, Humanities and Social Sciences courses	**36**
Cultural/Global Understandling	**9**
EUREKA! (First Year Seminar)	**6**
Science and Society Elective	**6**
ENGAGE in Wellness (3 courses)	**3**
ENGAGE in Service	**1**
ENGAGE in the Arts	**2**
Core@CMU	**3**
Free Electives	**15**
Minimum number of units required for the degree:	**388**

The above B.S. curriculum recommends a range of 41–50 units/semester to meet the minimum degree requirement. Students are strongly encouraged to take extra elective courses (except in the first year) in whatever subjects they wish in order to enrich their backgrounds and enhance their educational experience.

Some students may need to earn more than 388 units to complete their degree. Usually this happens when students earn AP Credit for a course (for example 09-105) and then take a class with the same or similar content (take 09-105 at CMU or 09-107). You cannot count 20 units towards a 10-unit requirement so this student would need to earn 398 total units.

NOTES ON ELECTIVES

Biological Chemistry Electives

A minimum of three biological chemistry electives for a total of 27 units or more is required.

A list of currently approved electives is provided below. Of the three elective courses at least two should be chemistry courses and a maximum of one can be taken in biology or physics. Exceptions can be granted by the Director of Undergraduate Studies. One semester of 09-445 for 9 units may be used for one biological chemistry elective with the approval of the Director of Undergraduate Studies. It must be part of a longer term experience ensuring depth of knowledge in the area.

09-403	Hooked: The Chemical Basis of Drug Addiction	9
09-518	Bioorganic Chemistry: Nucleic Acids and Carbohydrates (One of these two courses is required for the degree. The other can be used as a Biological Chemistry elective.)	9
or 09-519	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	
09-530	Chemistry of Gene Expression	9
or 09-730	Chemistry of Gene Expression	
09-538	Exposure and Risk Assessment for Environmental Pollutants	9
or 09-738	Exposure and Risk Assessment for Environmental Pollutants	
09-521	Metals in Biology: Function and Reactivity	6
09-737	Medicinal Chemistry and Drug Development	12
03-220	Genetics	9
03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	9
03-320	Cell Biology	9
03-344	Experimental Biochemistry	12
03-362	Cellular Neuroscience	9
03-366	Neuropharmacology: Drugs, Brain and Behavior	9
03-390	Molecular and Cellular Immunology	9
03-435	Cancer Biology	9
03-391	Microbiology	9
03-439	Introduction to Biophysics	10
03-442	Molecular Biology	9
03-729	Entrepreneurship and protein-based drug development	6
03-740	Advanced Biochemistry	12
03-871	Structural Biophysics	12
33-441	Introduction to Biophysics	10

Free Electives

Free electives are defined as including any course offered by Carnegie Mellon except those in science or engineering fields that are primarily intended for non-majors. A maximum of 9 units total of Physical Education, StuCo and/or ROTC courses combined can be counted as free elective units. The Chemistry Department does not require technical electives.

Minor in Chemistry

In order for a student to receive a minor in Chemistry in conjunction with a B.S. or B.A. degree from another (primary) department, the successful completion of six courses as distributed below is required. Students pursuing the minor must inform the Chemistry Department of their intentions in writing using the MCS form for declaration of a minor so that the minor designation can be approved prior to graduation. The form may be obtained from the MCS undergraduate webpage at www.cmu.edu/mcs/undergrad/advising/forms (http://www.cmu.edu/mcs/undergrad/advising/forms/). **It should be completed and submitted to the department office, DH 1317 (or keishawd@andrew.cmu.edu), no later than the end of the course add period of the final semester prior to graduation.** If you decide at a later date not to complete the minor, it would be helpful to notify the Director of Undergraduate Studies, Dr. Gizelle Sherwood, gsherwoo@andrew.cmu.edu (ks01@andrew.cmu.edu), so that it can be removed from your record. Minors are listed on the transcript but not on the diploma.

Note: An introductory chemistry class equivalent to either 09-105 Introduction to Modern Chemistry I or 09-107 Honors Chemistry: Fundamentals, Concepts and Applications is a **presumed prerequisite** to beginning the minor in chemistry.

Course Requirements

A. Four Required Core Courses

09-106	Modern Chemistry II	10
09-221	Laboratory I: Introduction to Chemical Analysis	9-12
or 09-207	Techniques in Quantitative Analysis	
09-217	Organic Chemistry I	9-10
or 09-219	Modern Organic Chemistry	
Choice of one of the following courses:		
09-331	Modern Analytical Instrumentation	9

09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-348	Inorganic Chemistry	10
09-507	Nanoparticles	9
09-529	Introduction to Sustainable Energy Science	9

Courses in this group that are not used to satisfy Part A core courses may be used to satisfy elective course requirements in part B below, provided they are **not** required by the student's primary department. A single course cannot count as a requirement and one of two electives.

B. Two Elective Courses from the following list.

09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-348	Inorganic Chemistry	10
09-222	Laboratory II: Organic Synthesis and Analysis	9-12
or 09-208	Techniques for Organic Synthesis and Analysis	
09-218	Organic Chemistry II	9-10
or 09-220	Modern Organic Chemistry II	
03-231/232	Honors Biochemistry	9
09-381	Environmental Systems on a Changing Planet	12
09-403	Hooked: The Chemical Basis of Drug Addiction	9
09-502/741	Organic Chemistry of Polymers	9
09-507/707	Nanoparticles	9
09-510/710	Chemistry and Sustainability	9
09-518/718	Bioorganic Chemistry: Nucleic Acids and Carbohydrates	9
09-519/719	Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry	9
09-524/724	Environmental Chemistry	9
09-525	Transition Metal Chemistry	9
09-530/730	Chemistry of Gene Expression	9
09-538/738	Exposure and Risk Assessment for Environmental Pollutants	9
09-563/763	Molecular Modeling and Computational Chemistry	9
09-615	Computational Modeling, Statistical Analysis and Machine Learning in Science	12
09-616	Neural Networks & Deep Learning in Science	12
09-621	Welcome to the Future Lab - Science in the Cloud must be taken with 09-623	6
09-714	Advanced Organic Chemistry	12
09-737	Medicinal Chemistry and Drug Development	12
09-760	The Molecular Basis of Polymer Mechanics	12
09-xxx	Approved Upper Level Chemistry Course (must be 09-3xx or higher but see exclusions noted below)	

Courses in this section (part B above) can not be counted toward the minor if they are required **in any way** by the student's primary department or towards an additional major or minor other than as a free elective. For example, students majoring in Biological Sciences can not double count 03-231 (or 03-232), 09-208 (or 09-222), or 09-218 (or 09-220) toward the elective courses for the minor in chemistry. Chemical engineering majors can not count 03-231 (or 03-232). Chemical engineering majors may be able to use one advanced chemistry elective in fulfillment of an additional requirement for the minor depending upon the course selected.

09-231 Mathematical Methods for Chemists, does not count towards the minor in chemistry. The undergraduate research course 09-445 Undergraduate Research and 09-435 Independent Study Chemistry cannot be used for the minor.

Since the pre-health program is a non-academic program as opposed to a minor or additional major, chemistry courses taken for that purpose can also count towards the minor provided they are not being used to also satisfy another minor, additional major or primary major.

Transfer credit will be accepted only for the prerequisite 09-105, or 09-106 and 09-217. All other classes towards the chemistry minor must be completed at Carnegie Mellon University.

Transfer Credit for Chemistry Courses

1. Requests for transfer credit for chemistry classes taken at other institutions should be made to Dr. Len Vuocolo, Associate Teaching Professor in the Department of Chemistry. Students making such requests should follow the policies and procedures in place within their home colleges in assembling materials for such requests. Consult with your advisor on the appropriate steps.
2. Requests should be placed **before** paying tuition for a class in case transfer credit is denied. Allow 1-2 weeks for approval.
3. At minimum requests must be accompanied by a complete syllabus including the textbook that will be used, a detailed list of topic areas preferably with a schedule showing the approximate amount of time spent on each topic, and an indication of whether or not the course is part of the curriculum for science majors at the other institution. Check to ensure that the institution is on a semester system. Most schools on a quarter system (many in the UC system of schools) teach general chemistry and organic chemistry over three quarters each; therefore one of these classes would not be equivalent to one CMU class.
4. The department no longer accepts fully online courses.
5. No transfer credit will be awarded for the laboratory classes required for the chemistry or biology major at Carnegie Mellon University, 09-207, 09-221, 09-208, 09-222, 09-321, 09-323 and 09-322. Requests for transfer credit for 09-101, Introduction to Experimental Chemistry, will be accepted with the appropriate documentation.
6. In assessing the suitability of courses for transfer credit, the following factors are considered:
    - The rigor of the course must be comparable to that offered at Carnegie Mellon. This is usually assessed via the quality of the institution and its chemistry program, the textbook used and the amount of time spent on topic areas. In general, the rate of approval is significantly higher for four-year institutions with science majors as opposed to community colleges.
    - The topic areas should match to a degree of at least 80% those covered in the comparable course at Carnegie Mellon University.
7. 09-105 Introduction to Modern Chemistry I focuses primarily on structure, bonding, interactions (and their influence on properties), and reactions (including quantitative relationships among substances in them). Detailed topics include the following:

- Radiation and Its Interaction with Matter
- Quantum Mechanics (wave-particle duality of matter, Heisenberg Uncertainty Principle)
- Atomic Structure (Schrodinger Model, quantum numbers, interpretation of orbitals and their relative energies)
- Interpretation of Periodic Table, including the writing of electron configurations, Aufbau Principle, and Hund’s Rule
- Periodic Table Trends in Elemental Properties
- Photoelectron Spectroscopy
- Bonding models and their explanation of properties (types of solids, bond polarity, bond energies, and bond lengths)
- Lewis Structures (octet rule and exceptions; formal charge)
- Resonance Structures
- Molecular shapes (including deviations from ideal bond angles)
- Molecular Polarity (greenhouse gases as application)
- Interparticle (intermolecular) forces and comparing or predicting relative physical properties from them (chromatography as application)
- Valence Bond (Localized Electron) and Molecular Orbital Theory
- Pi Molecular Orbitals (and energy diagrams) of Conjugated Organic Molecules
- Band Theory of Metals, Semiconductors, and Insulators
- Determining number of moles and chemical formulas
- Writing and balancing chemical equations (in particular completing combustion and double displacement reactions – including acid-base and precipitation reactions)
- Stoichiometry and thermochemical equations (heat evolved in combustion of fuels as application)
- Stoichiometry – limiting reactant and percentage yield
- Gases (mainly ideal) and stoichiometric applications involving them
- Phase transitions
- Solutions (determining concentrations, dilution problems, stoichiometric applications, application of solubility rules to determine if a precipitate forms)
- Acid-base reactions, titrations and other stoichiometric applications of acid-base reactions

- Oxidation Numbers, Redox Reactions/Titrations, and other stoichiometric applications of redox reactions

8. 09-106 Modern Chemistry II focuses primarily on thermodynamics, kinetics and equilibrium. Detailed topic areas include the following.

- Thermochemistry and Thermodynamics (First, Second, and Third Laws, with gas expansion/compression applications, including reversible, adiabatic processes)
- Internal energy, enthalpy, entropy, Gibbs Free energy, and determination of spontaneity
- Kinetics : Determination of rate, order, rate laws (including application of pseudo-rate laws, application of integrated rate law to determine order, relationship between time and amount in a reaction, and half-life
- Reaction mechanisms – applying fast equilibrium and steady-state approximations to determine rate law consistent with mechanism
- Chemical Equilibrium : determination of Q and K expressions, determination of direction in which reaction proceeds to achieve equilibrium (using Q and Le Chatelier's principles, quantitative calculations to determine K or amounts at various stages, dependence of K on temperature, relationship between Gibbs Free energy, Q, and K)
- Acid-Base Equilibria: writing dissociation equilibrium reactions and acid-base "neutralization" reactions, autoionization of water (determination of pH and pOH, use of K_w), writing K_a and K_b expressions from dissociation equilibria, quantitative equilibrium calculations for weak acids and bases, titrations between strong species, strong-weak species, and weak-weak species, buffers (calculations of pH and amounts, including how to make a buffer), polyprotic species (quantitative applications and titrations), solubility and precipitation equilibria, determination of K_{sp} expressions and quantitative applications of those expressions, complex ion formation equilibria, emphasis is placed on equilibrium problems that involve multiple types of simultaneous equilibria
- Electrochemistry: Electrochemical cell notation and writing half-reactions from it, Faraday constant to connect number of moles of electrons / reaction amounts with current, connection of Gibbs Free Energy to cell voltage (potential) at equilibrium and non-equilibrium conditions, determination of *K*'s (acid-base, solubility constants) or amounts using Nernst equation in concentration cells (*K* for cell reaction)

9. 09-111 Nanolegos: Chemical Building Blocks takes an applications or systems approach to exploring current significant research and technology, as well as to explaining phenomena and problems in the world around us. The major contexts and phenomena that it explore in applying and connecting chemical concepts are: (1) sustainable energy, (2) charge motion in materials, (3) natural versus engineered catalysts, (4) polymeric materials, and (5) reversible reactions in environmental and biological chemistry.

The chemical concepts used to promote an integrated understanding of the above applications and systems are:

- Radiation and Its Interaction with Matter
- Atomic Structure (Schrodinger Model, quantum numbers, interpretation of orbitals and their relative energies)
- Interpretation of Periodic Table, including the writing of electron configurations, Aufbau Principle, and Hund's Rule
- Periodic Table Trends in Elemental Properties
- Photoelectron Spectroscopy
- Bonding models and their explanation of properties (types of solids, bond polarity, bond energies, and bond lengths)
- molecular structures of organic and inorganic compounds
- Resonance Structures
- Molecular shapes
- Molecular Polarity
- Interparticle (intermolecular) forces and comparing or predicting relative physical properties from them
- Multiphase Reaction Stoichiometry (including limiting reactants and percent yield)
- Thermodynamics (First, Second, and Third Laws – applications more toward chemical reactions)
- Acid-Base Chemistry
- Kinetics (phenomenological and mechanistic)
- Electrochemistry (redox reactions; battery technology)
- Equilibrium

10. 09-101 Introduction to Experimental Chemistry is a seven week (mini) laboratory course that is designed to introduce students to some basic laboratory skills, techniques, and equipment commonly used in experimental chemical investigations. The experiments will apply concepts in organic and inorganic synthesis, quantitative analysis using visible spectrophotometry, kinetics, acid-base chemistry, thermochemistry, and transition metal coordination chemistry.

The chemical concepts applied or discovered in the course are:

- molecular polarity and interparticle (intermolecular) forces
- synthesis of substances (empirical formulas, stoichiometry, and percent yield),
- spectrophotometric analysis (dilution and Beer-Lambert Law)
- kinetics (integrated rate laws and Arrhenius equation)
- equilibrium (Law of Mass Action, LeChâtelier's Principle)
- acid-base equilibria
- redox reactions
- thermochemistry (enthalpy, thermochemical equations)
- coordination chemistry
- The Laboratory Skills/Techniques involved are:
- safe lab practices, waste disposal, and chemical hygiene
- data/observation recording in lab notebook
- graphing, analyzing, and interpreting experimental data
- use of top-loading balance
- chromatography (paper or silica plate)
- filtration (gravity and vacuum)
- recrystallization of solids
- titrations (redox and acid-base; use of pH meter)
- making of and dilution of solutions (including quantitative transfer of solute)
- use of volumetric pipet
- use of spectrophotometer
- developing experimental procedures

11. 09-217 Organic Chemistry I is a 9-unit course that is the first half of our two semester sequence in organic chemistry for non-majors. The concepts addressed in the class are listed below. Please take special note of the spectroscopy section. Many institutions do not introduce this topic in the first organic chemistry class. These concepts are especially important if you wish to take the second class, 09-218 Organic Chemistry II, and the organic laboratory class for non-majors, 09-208 Techniques for Organic Synthesis and Analysis. It is possible that you will be offered chemistry elective credit instead of transfer credit for 09-217 Organic Chemistry I if these topics are not addressed sufficiently in the class you submit for approval. The chemistry elective course might, with permission of your advisor, satisfy the organic chemistry requirement for your major, minor or additional major but not satisfy the prerequisite requirement for 09-218 Organic Chemistry II or 09-208 Techniques for Organic Synthesis and Analysis.

Topics:

· **Language of Organic Chemistry:**

o New concepts, chemical terms, and nomenclature.

o Chemical formulas and structural drawing.

o Use of arrows to represent electron flow to describe reaction mechanisms and chemical synthesis.

· **Molecular Structure:**

- Electronic structure and 3-dimensional structure of molecules: geometry.
- Arrangement of atoms in space: stereochemistry.
- Electron density on molecules or bonds is often non-homogeneous: polarity.

· **Spectroscopy:**

- Introduction to spectroscopic tools for structural analysis
- Infrared spectroscopy and molecular vibration. Functional group identification.
- Nuclear Magnetic Resonance (NMR) for structural elucidation from spectra.

· **Properties and Transformations:**

- Discuss properties and transformations of functional groups.
- Reagents that achieve different conversions and mechanisms.
- Introduction to chemical synthesis based on properties of functional groups.

- **Applications:**
  - Knowledge can be applied to:
    - Creating new materials.
    - Studying biological processes (e.g., cholesterol biosynthesis).
    - Understanding drug absorption and chemical transformations in the body.
    - Importance of enzymes and catalysts in organic reactions.
- **Learning Goals:**
  - Familiarize with above concepts and acquire skills to solve synthetic problems.
  - Analyze chemical reactions from different standpoints.

Academic Advising

"*I really love how close-knit the Department becomes over the course of four years. We are a relatively small department, so we get to truly become a family by the end of our time here. I actually think that experiencing college during a pandemic has made us even closer. Everyone in the Department is so supportive of each other rather than being cutthroat, which I really loved. I also really loved getting to perform in Murder Mystery for three years, because it really connected me with the students from the other years within the Department. " ~ 2022 Chemistry B.S.*

Building meaningful relationships related to your personal, academic and professional development should be a key component of your undergraduate experience. In the Department of Chemistry we believe that strong academic advising is key in facilitating this process. The Director of Undergraduate Studies is a Teaching Professor of Chemistry who acts as the academic advisor for all students with majors, additional majors and minors in chemistry. MCS students transition from their first year advisors in the Dean’s Office to their department advisor once they declare their majors, generally in the spring of their first year.

In the Department of Chemistry we are committed to the MCS philosophy that holistic advising with attention to the development of the whole person in all dimensions is key to success at CMU. Your academic advisor is certainly available for the more transactional processes such as developing a course schedule that allows you to make appropriate progress towards your degree. However more importantly she is also available to both be a resource and to point you towards additional connections to enable success in all aspects of your experience. You are encouraged to connect with your advisor early and build this relationship through scheduled and impromptu visits and e-mail, social events throughout the year as well as in the classroom. You will engage with your advisor in classes and seminars throughout your time as a major, facilitating a strong working relationship that will promote discussions of your successes, challenges and areas related to your health and well-being.

"*It was such a welcoming place. I never felt competition or animosity among students. Since it was so small, it felt close-knit and like the professors really knew you.*" *~ 2022 Chemistry B.S.*

In the Department of Chemistry most students find additional faculty mentors in small, personalized classroom experiences but even more significantly through undergraduate research where participation generally exceeds 95% in any given graduating class.

Faculty

BRUCE A. ARMITAGE, Professor and Department Head of Chemistry, Co-Director Center for Nucleic Acids Science and Technology – Ph.D., University of Arizona; Carnegie Mellon, 1997–

STEFAN BERNHARD, Professor of Chemistry – Ph.D., University of Fribourg (Switzerland); Carnegie Mellon, 2009–

MARK E. BIER, Research Professor of Chemistry and Director of the Center for Molecular Analysis – Ph.D., Purdue University; Carnegie Mellon, 1996–

EMILE BOMINAAR, Associate Research Professor of Chemistry – Ph.D., University of Amsterdam (The Netherlands); Carnegie Mellon, 1994–

TERRENCE J. COLLINS, Teresa Heinz Professor in Green Chemistry and Director of the Institute for Green Science – Ph.D., University Auckland, (New Zealand); Carnegie Mellon, 1988–

SUBHA R. DAS, Associate Professor of Chemistry – Ph.D., Auburn University; Carnegie Mellon, 2006–

NEIL M. DONAHUE, Thomas Lord University Professor of Chemistry, Professor of Chemical Engineering and Engineering and Public Policy and Director of the Steinbrenner Institute for Environmental Education and Research – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2000–

SIMON FAULKNER, Assistant Teaching Professor of Chemistry at Carnegie Mellon University- Qatar – Ph.D., University College London (United Kingdom); Carnegie Mellon, 2019–

ISSAAC GARCIA-BOSCH, Associate Professor of Chemistry – Ph.D., University of Girona, Catalonia (Spain); Carnegie Mellon, 2021–

ROBERTO GIL, Research Professor of Chemistry and Director of the NMR Facility – Ph.D., Córdoba National University (Argentina); Carnegie Mellon, 2002–

GABRIEL DOS PASSOS GOMES, Assistant Professor of Chemistry and Chemical Engineering – Ph.D., Florida State University; Carnegie Mellon, 2022–

YISONG (ALEX) GUO, Associate Professor of Chemistry – Ph.D., University of California at Davis; Carnegie Mellon, 2014–

MICHAEL P. HENDRICH, Professor of Chemistry – Ph.D., University of Illinois; Carnegie Mellon, 1994–

OLEXANDR ISAYEV, Professor of Chemistry – Ph.D., Jackson State University; Carnegie Mellon, 2020–

RONGCHAO JIN, Professor of Chemistry – Ph.D., Northwestern University; Carnegie Mellon, 2006–

ANNA KIETRYS, Assistant Professor of Chemistry – Ph.D., Polish Academy of Sciences (Poland); Carnegie Mellon, 2020–

HYUNG J. KIM, Professor of Chemistry – Ph.D., State University of New York at Stony Brook; Carnegie Mellon, 1992–

TOMASZ KOWALEWSKI, Professor of Chemistry – Ph.D., Polish Academy of Sciences (Poland); Carnegie Mellon, 2000–

MARIA KURNIKOVA, Professor of Chemistry – Ph.D., University of Pittsburgh; Carnegie Mellon, 2003–

DANITH LY, Professor of Chemistry – Ph.D., Georgia Institute of Technology; Carnegie Mellon, 2001–

KRZYSZTOF MATYJASZEWSKI, J.C. Warner University Professor of Natural Sciences and Co-Director of the Center for Polymer-Based Protein Engineering and Director of the Center for Macromolecular Engineering – Ph.D., Polish Academy of Sciences (Poland); Carnegie Mellon, 1985–

CARRIE MCDONOUGH, Assistant Professor of Chemistry – Ph.D., University of Rhode Island; Carnegie Mellon, 2022–

NIMER MURSHID, Assistant Teaching Professor – Ph.D. , University of Waterloo; Carnegie Mellon, 2023-–

KEVIN NOONAN, Professor of Chemistry and Associate Department Head – Ph.D., University of British Columbia (Canada); Carnegie Mellon, 2011–

LINDA A. PETEANU, Professor of Chemistry – Ph.D., University of Chicago; Carnegie Mellon, 1992–

GIZELLE SHERWOOD, Teaching Professor and Director of Undergraduate Studies and Laboratories – Ph.D. , Carnegie Mellon University; Carnegie Mellon, 2009–

GLORIA SILVA, Teaching Professor of Chemistry – Ph.D., Universidad Nacional de Córdoba (Argentina); Carnegie Mellon, 2002–

KAREN H. STUMP, Teaching Professor of Chemistry – M.S., Carnegie Mellon University; Carnegie Mellon, 1983–

RYAN SULLIVAN, Professor of Chemistry and Mechanical Engineering and Associate Director of the Institute for Green Science – Ph.D., University of California at San Diego; Carnegie Mellon, 2012–

STEFANIE SYDLIK, Associate Professor of Chemistry – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2015–

LEONARD VUOCOLO, Associate Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2005–

NEWELL WASHBURN, Associate Professor of Chemistry and Biomedical Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 2004–

DAVID YARON, Professor of Chemistry – Ph.D., Harvard University; Carnegie Mellon, 1992–

Emeriti

GUY C. BERRY, University Professor Emeritus of Chemistry and Polymer Science – Ph.D., University of Michigan; Carnegie Mellon, 1960–

JOSEF DADOK, Professor Emeritus of Chemical Instrumentation – Ph.D., Czechoslovak Academy of Sciences; Carnegie Mellon, 1967–

REA FREELAND – PhD, Carnegie Mellon University; Carnegie Mellon, 1993–

SUSAN T. GRAUL, Associate Teaching Professor Emerita of Chemistry – Ph.D., Purdue University; Carnegie Mellon, 1992–

PAUL J. KAROL, Professor Emeritus of Chemistry – Ph.D., Columbia University; Carnegie Mellon, 1969–

ECKARD MÜNCK, Professor Emeritus of Chemistry – Ph.D., Technical University of Darmstadt (Germany); Carnegie Mellon, 1990–

GARY D. PATTERSON, Professor Emeritus of Chemistry – Ph.D., Stanford University; Carnegie Mellon, 1984-.–

STUART W. STALEY, Professor Emeritus of Chemistry – Ph.D., Yale University; Carnegie Mellon, 1986–

Adjunct Faculty

BERNARD CRIMMINS, Adjunct Associate Professor of Chemistry and Associate Professor, Department of Civil Engineering, Clarkson University and President of Academic Environmental/Analytical Consulting Services (AEACS), LLC. – Ph.D., University of Maryland; Carnegie Mellon, 2018–

JOHN PETERSON MYERS, CEO and Chief Scientist of Environmental Health Sciences – Ph.D., University of California at Berkeley; Carnegie Mellon, 2010–

JAMES PETERSON, Adjunct Associate Professor of Chemistry and Associate Professor of Environmental and Occupational Health at the University of Pittsburgh – Ph.D., University of Essex, UK; Carnegie Mellon, 2004–

Courtesy

MICHAEL BOCKSTALLER, Professor of Materials Science Engineering and Faculty of Chemistry – Ph.D., Johannes Gutenberg University (Germany); Carnegie Mellon, 2005–

ANDREW GELLMAN, Lord Professor of Chemical Engineering and Co-Director W.E. Scott Institute for Energy Innovation – Ph.D., University of California, Berkeley; Carnegie Mellon, 1992–

NOA MAROM, Assistant Professor of Materials Science Engineering and Faculty of Chemistry – Ph.D., Weizmann Institute of Science (Israel); Carnegie Mellon, 2016–

GORDON RULE, Professor of Biological Sciences and Head of CMU Qatar Biological Sciences Program and Faculty of Chemistry – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1995–

ALAN J. RUSSELL, Highmark Distinguished Career Professor of Chemical Engineering and Director of Disruptive Health Technology Institute – Ph.D., Imperial College of London; Carnegie Mellon, 2012–

JAMES SCHNEIDER, Professor of Chemical Engineering and Faculty of Biomedical Engineering and Chemistry – Ph.D., University of Minnesota; Carnegie Mellon, 1999–

LYNN WALKER, Professor of Chemical Engineering and Faculty of Chemistry and Materials Science Engineering – Ph.D., University of Delaware; Carnegie Mellon, 1997–

JOHN L. WOOLFORD JR., Professor of Biological Sciences; Co-Director of Center for Nucleic Acids Science and Technology and Faculty of Chemistry – Ph.D., Duke University; Carnegie Mellon, 1979–

Department of Chemistry Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

09-052 Summer Internship

Summer: 3 units
The Department of Chemistry considers experiential learning opportunities important educational options for its undergraduate students. One such option is an internship, normally completed during the summer. Students do not need to officially register for an internship unless they want it listed on their official transcripts. The Director of Undergraduate Studies (or designee) will add the course to the student's schedule, and the student will be assessed tuition for 3 units. Upon completion of the internship, students must submit a 1-2 page report on their work experience to the Director of Undergraduate Studies (or other designated faculty member). Verification by the internship supervisor must be received prior to a grade being awarded. After the reports have been reviewed and approved, and verification received, a "P" grade will be assigned. Special permission of Instructor is required to register for this course.

09-101 Introduction to Experimental Chemistry

All Semesters: 3 units
This is a seven week chemistry laboratory course that is designed to introduce students to some basic laboratory skills, techniques, and equipment commonly used in experimental chemical investigations. The experiments will apply concepts in organic synthesis, quantitative analysis using visible spectrophotometry, kinetics, acid-base chemistry, thermochemistry, transition metal chemistry, and chromatography. 1 hr. lec., 3 hrs. lab.

09-103 Atoms, Molecules and Chemical Change

Fall: 9 units
Atoms, Molecules and Chemical Change is a self-contained one-semester introductory college chemistry course for students who have a high-school background in science and mathematics but who have decided not to major in a STEM field (science, technology, engineering, or mathematics). Students will develop fundamental chemical knowledge in topics such as stoichiometry, atomic theory, molecular bonding and structure, chemical reactions, thermodynamics, and electrochemistry. This knowledge will be applied to a variety of topics, including biological, industrial, environmental, agricultural, and culinary applications, helping students to understand how chemistry affects environmental, social, political, and economic issues. Through this course, students will develop both qualitative understanding and quantitative skills in chemistry. Students with credit for 09-105 or other more advanced chemistry courses are not permitted to enroll in this course. 3 hrs. lec., 1 hr. rec.

09-105 Introduction to Modern Chemistry I

Fall and Spring: 10 units
This course first investigates the establishment of some fundamental principles of chemistry and then progresses through the presentation of chemically interesting applications and sophisticated problems. It explores an understanding of matter and the energy changes associated with it, beginning with the atom. It then overviews how atoms interact and react to form the more complicated structures of molecules and ionic compounds. How the structure of elements and compounds affects their properties, function, and reactivity will then be explored. Finally, the quantification of the changes during the reactivity of substances through bond breaking and forming will be investigated in single and multiple phase reactions, such as acid-base and redox reactions. Topics will be presented to promote mastery of "depth over breadth of topics" and "conceptual understanding before using applicable equations". The course covers the major principles of atomic structure, chemical bonding, , molecular structures of organic and inorganic compounds (including some transition metal complexes), interaction of substances, multiphase reaction stoichiometry, acid-base reactions, and redox reactions. Relevant examples will be drawn from such areas as environmental, materials, and biological chemistry.

09-106 Modern Chemistry II

Fall and Spring: 10 units
This course provides an overview of thermodynamics, kinetics and chemical equilibrium. Topics include the flow of energy in chemical systems; the spontaneity of chemical processes, i.e. entropy and free energy; the mechanisms and rates of chemical reactions; and the use of chemical equilibrium to reason about acid-base chemistry, solubility and electrochemistry. Applications include the energy economy, biological systems and environmental chemistry. 3 hrs. lec., 2 hrs. rec.
Prerequisites: 09-105 or 09-107

09-107 Honors Chemistry: Fundamentals, Concepts and Applications

Fall: 10 units
This is an honors introductory course designed to provide students with a rigorous coverage of general chemistry in the context of grand challenges in the field. Traditional topics, such as equilibrium, kinetics, acid-base chemistry, and quantum chemistry, will be discussed through current research on nucleic acid-based therapeutics, atmospheric chemistry of pollutants, and catalysts for the production of solar fuels. The approach will integrate traditional lectures and readings from the textbook with discussions of journal articles, on-line content on research methods, and guest lectures from CMU faculty in these areas. This course assumes strong preparation in chemistry (AP Chemistry score of 3 or greater; IB Chemistry score of 5 or greater; SAT II Chemistry exam with a score of 700 or greater) and will be offered at an accelerated pace. The goal is to teach core principles of chemistry while exposing students to the diversity of modern chemical research and how it is addressing grand challenges facing society. 3 hrs. lec., 2 hrs. rec.

09-108 The Illusion and Magic of Food

Fall: 6 units
Have you ever wondered about your food? Why the freshly squeezed orange juice spoils after few hours while the one from the market lasts so much longer without apparent alteration? Why roasted food is so delicious? What is the nutritional value of milk and honey? Why soft drinks are damaging the teeth? What is the Impossible Burger? These and many more questions will be answered in this course, not only by the instructor but also through the student's research and curiosity. This course will introduce chemistry concepts on an as-needed basis, but it will remain at a simple level. We expect to help the student understand what food is made of, its nutritional value, how it is processed to offer longer shelf life, and how elaboration and preservation procedures may affect critical components. The topics will vary depending on the student's motivation in learning about different concepts related to the food industry, from processing to analysis, to packaging, and appearance. We plan to discuss interesting things in every class and finish the course with a broad knowledge of what is on our table and a better criteria to select our food. 3 hrs. lectures per week.

09-109 Kitchen Chemistry Sessions

Intermittent: 3 units
Ever wanted to boil water in ice? Cook an egg so the yolk is set but the white still runny? Lick a lemon or drink vinegar but have it taste sweet? Make "caviar" from fruit juice and noodles from yogurt? Explore the science of molecular gastronomy through the lectures and demonstrations that reveal the chemistry and biochemistry of food ingredients and their preparation. Then use a kitchen as your "laboratory" to test hypotheses and delve into molecular cooking - you may just get to eat your lab results. For this course high school background in chemistry would help but nothing more advanced is required. Concepts will be discussed on a need to know basis. Students with stronger chemistry backgrounds should enroll in 09-209. 3 hrs. lec. and lab

09-110 The Design and Making of Skin and Hair Products

Spring: 3 units
This hands-on course targets students from across the CMU community who are interested in learning how chemistry applies to their everyday life. We will focus on students gaining knowledge of the chemical components in cosmetic products and on the methods for preparing them (from shampoos and conditioners to lotions, soaps, and creams). We will emphasize good laboratory practices and safety as well as the fundamental chemical and physical concepts that govern the product behavior and use. The overarching goal is that the students have a hands-on laboratory experience and develop a full understanding of the science behind the products that they use every day. No human or animal testing will take place as part of the curriculum.

09-111 Nanolegos: Chemical Building Blocks

Fall: 9 units
How does chemistry provide the foundation and building blocks in science, engineering, and technology? How does activity on the particle and molecular level that we cannot see cause things to happen and function on a level we CAN observe? What basic chemical concepts are needed as tools to understand current significant research and technology, as well as to understand phenomena and problems in the world around us? This course will emphasize answering these questions by presenting "problem- or context-first", then applicable chemical concepts on an as-needed basis. It is structured around phenomena relevant to modern society, research, and technology rather than the conceptual tools (i.e. systems- or application-, rather than content-driven). Many of the conceptual tools (e.g. structure, interaction between energy and matter, interparticle forces, reaction stoichiometry, thermodynamics and kinetics) are used throughout the course, to help reinforce these ideas and promote an integrated understanding. The major contexts and phenomena that we will explore in applying and connecting chemical concepts are: (1) sustainable energy, (2) charge motion in materials, (3) natural versus engineered catalysts, (4) polymeric materials, and (5) reversible reactions in environmental and biological chemistry

09-114 Basics of Food Science

All Semesters: 3 units
Food is essential for life and the maintenance of health. As consumers we know little about its constitution and processing. This course will shed light upon the main nutrients found in food and their properties. We will discuss the importance of different processing techniques and about the ingredients added to food that extend its shelf life, or that improve its mouthfeel, and appearance. Overall, this course aims to make students aware of the intrinsic value of food, and how its manipulation and eventual reconstitution leads to an acceptable final product found in the supermarket.

09-115 Introduction to Undergraduate Research in Chemistry

Fall: 2 units
Undergraduate research is an important activity in the training of undergraduate chemistry majors. This course is intended for students who are planning to declare a major in chemistry who are novices to research at the university level and have an interest in being better informed about strategies and skills that contribute to success. It is intended that this course will lead to an opportunity to participate in a series of shadowing opportunities through a second course in the spring semester where students will be mentored by upperclass students or PhD candidates in faculty laboratories. Spaces will be reserved for MCS students. Students from other colleges with a strong interest in a chemistry major or additional major should contact the Director of Undergraduate Studies in the Chemistry Department.

09-116 Undergraduate Research Shadowing in Chemistry

Spring: 2 units
This is a follow-up course to 09-115, Introduction to Undergraduate Research in Chemistry, which is intended to provide laboratory training for first-year MCS students who want to participate in research in chemistry as soon as their first year, but have not been through the teaching labs yet. Near the end of the fall mini for 09-115, students will be asked to rank their faculty/group interests for possible shadowing. Based on those rankings and faculty/mentor availability, in 09-116, students will be paired with mentors from research labs for seven-week shadowing experiences. Mentors may be graduate students or advanced undergraduate students carrying out research. At the beginning of each mini, the students and mentors will identify blocks of time each week for shadowing based on their schedules. If scheduling allows, students will also be encouraged to attend group meetings (this would count toward lab time). Shadowing will continue for seven weeks, at which time the students may rotate to a second group for another shadowing experience. We request a dedicated lecture room to ensure there is adequate space for the initial pairing and for an overview on assessments, and to allow for possible additional meetings as the course develops.
Prerequisite: 09-115 Min. grade C

09-122 Molecular Tools for Biological and Chemical Studies

Spring: 6 units
Fluorescent dyes are applied in numerous fields to aid in tasks such as mapping the course of water underground, examining the eye, and detecting biological events. This course is aimed at offering a hands-on laboratory experience in the interface of chemistry and biology, also known as bioorganic chemistry. In this lab students will learn about fluorescence and fluorescent compounds. They will prepare a dye and will measure its fluorescent properties in presence of different media. This behavior will be compared and contrasted with that of another dye that will be provided. A former student in the course says: "Molecular Tools for Biological and Chemical Studies was one of the highlights of my time at CMU! Taking this course during my freshman year allowed me to gain skill and confidence in the lab, and the concepts I learned helped me to excel in many other courses I took at CMU (including: Organic Chemistry I and amp; II, Laboratory I: Introduction to Chemical Analysis, Laboratory II: Organic Synthesis and Analysis, Biochemistry, and Modern Analytical Instrumentation). Since graduating from CMU, I have been working on a Ph.D. in chemical biology. I still use many of the skills that I learned in Molecular Tools on a daily basis." Maddie Balzarini

09-201 Undergraduate Seminar I

Fall: 1 unit
Issues and topics of importance to beginning chemistry majors are discussed in this course. It provides a general introduction to the facilities, faculty and programs of the Department of Chemistry and introduces students to career and research opportunities in the field of chemistry. Enrollment limited to students majoring in chemistry. 1 hr.

09-202 Undergraduate Seminar II: Safety and Environmental Issues for Chemists

Spring: 1 unit
Issues and topics focused on laboratory safety are discussed in this class. The topics are selected to supplement information covered in 09-221, Laboratory I. This course is intended to provide the necessary safety training for students wishing to undertake undergraduate research projects in the laboratory and is taught in collaboration with the Office of Environmental Health and Safety. Enrollment is limited to chemistry majors. 1 hr.

09-204 Professional Communication Skills in Chemistry

Spring: 3 units
This required course for chemistry majors promotes development of written and oral communication skills in various formats within the discipline. Students are expected to develop these skills by becoming more familiar with the style and format of the chemical literature, current topics in chemistry, and research projects in the Department. Other learning outcomes include developing critical reading skills, providing effective feedback to peers' written and oral communication, demonstrating the ability to revise written work, and using chemical structure drawing software. 1 hr. lec.
Prerequisite: 09-221

09-207 Techniques in Quantitative Analysis

Fall: 9 units
09-207 is the first of two chemistry lab courses required for the BS and BA degrees in biological sciences and the intercollege major in biological sciences and psychology. It is also suitable for fulfilling the requirement for two general chemistry labs for admission to programs in the health professions. The experimental work emphasizes the techniques of quantitative chemical analysis. Included are projects dealing with a variety of instrumental and wet chemical techniques. A mixture of individual and partner experiments are conducted during the semester. In addition to laboratory techniques, safety, and written communication skills are emphasized.
Prerequisites: 09-107 Min. grade A or 09-106

09-208 Techniques for Organic Synthesis and Analysis

Intermittent: 9 units
09-208 is the second of two chemistry laboratory courses required for the BS in biological sciences and the intercollege major in psychology and biological sciences. It is also suitable for fulfilling the requirement for the laboratory experience for application to programs in the health professions. The course emphasizes experimental work in separations, synthesis, and analysis of organic compounds, including chromatography and spectroscopy. Written communication skills will be developed by means of laboratory reports and essays. 1.5 hr lec, 5 hrs lab
Prerequisites: (09-217 or 09-219) and (09-221 or 09-207 or 09-223)

09-209 Kitchen Chemistry Sessions

Intermittent: 3 units
Ever wanted to boil water in ice? Cook an egg so the yolk is set but the white still runny? Lick a lemon or drink vinegar but have it taste sweet? Make "caviar" from fruit juice and noodles from yogurt? Explore the science of molecular gastronomy through the lectures and demonstrations that reveal the chemistry and biochemistry of food ingredients and their preparation. Then use a kitchen as your "laboratory" to test hypotheses and delve into molecular cooking - you may just get to eat your lab results. Students enrolling in this course are assumed to have a college level background in chemistry including introductory organic chemistry. Students without a solid chemistry background should take the lower level 09-109. 3 hrs. lec. and lab
Prerequisites: 09-219 or 09-217

09-214 Physical Chemistry

Spring: 9 units
This is a one-semester course intended primarily for students majoring in Biological Sciences, students pursuing a B.A. degree program in Chemistry, and students in the B.S.A.program with a concentration in chemistry. The course focuses on thermodynamics, transport and reaction rates and their application to chemical and biological systems. Emphasis is given to attaining a good fundamental understanding of entropy and free energy. This is more a concepts than skills building course. Topics include applications of thermodynamics to chemical and biochemical equilibria, electrochemistry, solutions, and chemical kinetics. 3 hrs. lec.
Prerequisites: 09-106 and (21-122 or 21-124) and (33-141 or 33-121 or 33-111 or 33-106)

09-215 Chemistry Tech I to Lab I Transition

Fall and Spring: 3 units
09-215 is a 3-unit course intended for students who have taken 09-207, Techniques in Quantitative Analysis, who decide later in their academic experience that they wish to pursue a degree or an additional major in chemistry. The chemistry major requires a 12-unit lab class, 09-221 Laboratory I: Introduction to Chemical Analysis. This course will utilize self-study and problem solving to introduce or reinforce key concepts covered in 09-221 that are not introduced or are de-emphasized in 09-207. Students will also propose an idea for an independent lab-based project and carry it through all stages of development but not perform the actual lab work. The project development will require written work products as well as an oral presentation. The course must be completed before the last semester of the students degree program.
Prerequisite: 09-207 Min. grade C

09-216 Chemistry Tech II to Lab II Transition

Fall: 3 units
09-216 is a 3-unit course intended for students who have taken 09-208, Techniques in Organic Synthesis and Analysis, who decide later in their academic experience that they wish to pursue a degree or an additional major in chemistry. The chemistry major requires a 12-unit lab class, 09-222 Laboratory II: Organic Synthesis and Analysis. This course will utilize self-study and problem solving to introduce or reinforce key concepts covered in 09-222 that are not introduced or are de-emphasized in 09-208.

09-217 Organic Chemistry I

Fall: 9 units
This course presents an overview of structure and bonding as it pertains to organic molecules. Selected topics include: introduction to functional group chemistry, stereochemistry, conformational analysis, reaction mechanisms and use of retrosynthetic analysis in the development of multistep syntheses. Methods for structure determination of organic compounds by modern spectroscopic techniques are introduced. 3 hrs. lec., 1 hr. rec.
Prerequisites: 09-105 or 09-107

09-218 Organic Chemistry II

Spring: 9 units
This course further develops many of the concepts introduced in Organic Chemistry I, 09-217. Emphasis is placed on the utilization of reaction mechanisms for understanding the outcome of chemical transformations, and the employment of a wide variety of functional groups and reaction types in the synthesis of organic molecules. Also included in the course will be special topics selected from the following; polymers and advanced materials, biomolecules such as carbohydrates, proteins and nucleic acids, and drug design. 3 hrs. lec., 1 hr. rec.
Prerequisites: 09-217 or 09-219

09-219 Modern Organic Chemistry

Fall: 10 units
Traditional introductory organic chemistry courses present structure, reactivity, mechanisms and synthesis of organic compounds. Students taking 09-219 will be exposed to the same topics, but presented in greater depth and broader context, with applications to allied fields such as (1) polymer and materials science, (2) environmental science and (3) biological sciences and medicine. This will be accomplished through an extra 50 minute lecture period, where more advanced topics and applications will be discussed. Topics will include computational chemistry, green chemistry, chiral separations, photochemistry, reaction kinetics, controlled radical polymerizations and petroleum cracking. Students who complete 09-219 will have a strong foundation in organic chemistry as well as a sophisticated understanding of how organic chemistry is currently practiced. 4 hrs. lec., 1 hr. rec.
Prerequisites: 09-106 or 09-107 Min. grade A

09-220 Modern Organic Chemistry II

Spring: 10 units
This course builds on 09-219 by introducing students to additional functional groups, chemical reaction mechanisms and synthetic strategies commonly used in the practice of organic chemistry. Advanced topics to be presented during the extra lecture will include multidimensional NMR spectroscopy, enantioselective synthesis, ionic polymerization, bioorganic and medicinal chemistry, natural products chemistry and toxicology. Students who complete 09-220 will have a strong foundation in synthetic, mechanistic and structural organic chemistry and will understand how this applies to human health and the environment. 4 hrs. lec, 1 hr. rec.
Prerequisite: 09-219

09-221 Laboratory I: Introduction to Chemical Analysis

Fall and Spring: 12 units
This course is the first in a sequence of four laboratory courses on experimental aspects of chemistry required for the B.S. and B.A. degrees in chemistry. The experimental work emphasizes the techniques of quantitative chemical analysis. Included are projects dealing with a variety of instrumental and wet chemical techniques. The course is project-oriented with the experiments becoming more complex, requiring greater student input into the experimental design as the semester progresses. A mixture of individual and team experiments are conducted during the semester. In addition to techniques, safety, written and oral communication skills, and effective teamwork are emphasized. 2 hrs. lec., 6 hrs. lab.
Prerequisites: 09-106 or 09-107 Min. grade A

09-222 Laboratory II: Organic Synthesis and Analysis

Fall and Spring: 12 units
In this second course in the laboratory sequence, students acquire laboratory skills relevant to synthesis and purification of organic compounds, as well as the practical use of chromatography and spectroscopy. Students will also further develop technical writing skills through preparation of lab reports. 2 hrs. lec., 6 hrs. lab.
Prerequisites: (09-219 or 09-217) and (09-223 or 09-221)

09-224 Supramolecular Chemistry

Intermittent: 3 units
Supramolecular chemistry involves the use of noncovalent bonding interactions to assemble molecules into stable, well-defined structures. This course will provide students with an introduction to this exciting field of research, which is finding increasing applications in the biological and materials sciences, nanotechnology and medicine. Students will be introduced to essential background concepts such as types of noncovalent bonding and strategies for the design of supramolecular assemblies. Readings from monographs and classroom lectures by the instructor will cover this material. Students will then begin to read about applications of supramolecular chemistry from the scientific literature, learning to compare articles, to evaluate the quality of the data and interpretations reached by the authors, to use the knowledge gained from these readings and discussions to predict the outcomes of related experiments, and to ultimately be able to design their own experiments to answer research questions. Meeting hours set by instructor, enrollment limited with priority given to sophomore chemistry majors.
Prerequisites: 09-219 Min. grade C or 09-217 Min. grade C

09-225 Climate Change: Chemistry, Physics and Planetary Science

Fall: 9 units
Understanding the essential features of climate and climate change is a critical tool for modern citizens and modern scientists. In addition, the prevalence of climate skepticism in modern political discourse requires of citizens that they be able to think critically about a technical subject and also be able to distinguish reliable scientific experts from advocates. In this course we shall examine the climate of terrestrial planets (specifically Earth and Venus) through geological time and to the present, considering geochemical methods used to determine atmospheric composition over Earths history (specifically the onset of oxygen in the atmosphere as well as the relationship between carbon dioxide and global temperature over geological timescales. The shorter climate history of Venus will be considered as a counter example, where the brightening dim young sun overwhelmed negative feedbacks in the weathering cycle, leading to a runaway greenhouse amplified by complete evaporation of the onetime Venus ocean. Throughout the course, we will consider climate change driven by human activity since the industrial revolution as a unifying theme.
Prerequisites: (09-107 or 09-105) and (33-141 or 33-121 or 33-151)

09-227 The Culture of Color: Dyes, Chemistry, and Sustainability

All Semesters: 9 units
ne of the earliest forms of proto-chemistry, dyeing textiles has a long history of rich cultural traditions and technical innovations - which we will explore and practice. In this course students will focus on color through working with dyes for textiles scientifically, artistically, and culturally. You will learn the chemical science of color and techniques to isolate natural pigment for dyes as well as how to produce dyes synthetically. Students learn a variety of methods to apply our dyes to textiles to create beautiful patterns: immersion dyeing, resist and folding techniques, and printing. You will be exposed to the use of laboratory equipment and will be trained in good laboratory practices and safety. In preparation for your final project, throughout the course, we will discuss the cultural significance of colors, the origin of pigments, their production impact on the economy of the area, sustainability, and environmental impact of the waste produced by the textile dyeing industry.

Course Website: http://www.chem.cmu.edu/

09-231 Mathematical Methods for Chemists

Fall: 9 units
This course uses mathematical approaches to develop models for chemical systems and materials from the bottom up, i.e. from atoms and molecules to substances. This course focuses on statistical mechanics and does not cover quantum mechanics basics. Math will be covered in the context of chemical phenomena, and combine topics from probability theory and statistics, 3-dimensional calculus, differential equations, and linear algebra. 3 hrs. lec.
Prerequisites: (09-107 Min. grade A or 09-106) and (21-124 or 21-122)

09-291 Environmental Systems on a Changing Planet

Fall: 9 units
This course introduces the interconnected environmental systems that regulate our climate and ecosystems, providing the resources required to sustain all life, including human societies. These systems are the fascinating connections between the oceans, atmosphere, continents, ecosystems, and people that provide our planet with resources that all life depends on. Human activities disrupt these natural systems, posing critical threats to the sustainable functioning of environmental systems. We will explore how solar and biochemical energy moves through the Earths interconnected systems, recycling nutrients; how complex environmental systems function to produce critical resources such as food and water; and how human activities interfere with these systems. Case studies include the interplay between climate change feedbacks, wildfires, and forest ecosystems; the hazards that everyday chemical toxins pose to ecosystems and human health and reproduction; and growing threats to ecosystem health and biodiversity. We will also develop the relevant information literacy required to understand current issues that are frequently debated in the public sphere, and connect these to environmental justice. This course draws on principles learned in high school science and serves as the foundational Earth and amp; Environmental Science requirement for both the Minor and Additional Major in Environmental and Sustainability Studies. 09-291 is intended for both non-STEM majors from any program as well as STEM majors from any program in CIT, MCS, and SCS. In addition, STEM majors are strongly encouraged to take the connected 09-381 3-unit course that provides a more technical and quantitative framework for understanding the course content. 24-381 is often required for this course to count as a technical elective for STEM programs, and is required for students from CIT, MCS, and SCS in the Environmental and Sustainability Studies programs.

09-301 Undergraduate Seminar III

Fall: 1 unit
Students attend seminars on current topics in chemistry. Students are sent a menu of choices for each week of the semester and may select topics of interest. Enrollment is restricted to students majoring in chemistry. 1 hr.

09-302 Undergraduate Seminar IV

Spring: 1 unit
Students attend seminars presented by senior chemistry majors. Students provide peer evaluations of the seminars and through the process students become familiar with special topics in chemistry. The course establishes what should be included in a good seminar. This seminar courses is one of 6 required for the chemistry major. If a schedule conflict exists, students may, with permission of the instructor, attend other chemistry seminars or make other arrangements to fulfill the requirement. 1 hr.

09-303 Hooked: The Molecular Basis of Addiction

Fall: 6 units
What makes us need something so much that it eclipses the most important aspects of our lives, such as family, friends, work, hobbies, health and wellness? There are many different types of addiction; this course will focus on molecular addictions, with an emphasis on those involving members of the opioid class of narcotics. The ongoing epidemic of opioid addiction, arising both from over-prescription of pain killers and recreational use of heroin, has been widely reported and continues to rise at alarming rates, ravaging our urban and rural communities. In this course, we will explore the complicated role of chemistry in this epidemic, including the good (elucidating mechanisms of action, developing clinically useful and safe opioids and non-opioids) and the bad (design and synthesis of increasingly addictive opioids). We will also discuss ethical questions faced by the pharmaceutical industry that develops, markets and sells these drugs, the medical community that prescribes them, the government agencies charged with regulating these activities and law enforcement agencies that attempt to stop the flow of drugs into and within the United States. The second half of the semester will focus on addiction to other drugs, including cocaine, marijuana, amphetamines, alcohol and nicotine. We will also discuss chemical approaches to treating addiction. Students who complete this course will emerge with a broad understanding and perspective on an issue that is of great scientific and societal importance. The course will be organized in units that begin with a historical/societal "big picture" overview, followed by technical discussions of the underlying chemistry and biochemistry, concluding with consideration of the societal implications of addiction to each particular substance.

09-321 Laboratory III: Molecular Design and Synthesis

Fall: 12 units
In this third course in the laboratory sequence, students will learn a variety of more advanced techniques for organic synthesis and characterization, and will gain experience with developing and designing synthetic procedures. Student writing skills are further reinforced through preparation of detailed lab reports. 2 hrs. lec., 6 hrs. lab.
Prerequisites: (09-220 or 09-218) and 09-222

09-322 Laboratory IV: Molecular Spectroscopy and Dynamics

Spring: 12 units
This laboratory course is devoted to physical chemistry experiments, which involve the use of modern spectroscopic instrumentation to probe the optical and magnetic properties of molecules. The experiments include the use of high-resolution infrared, laser Raman, NMR, EPR, fluorescence, and UV-visible spectroscopies. Additional experiments demonstrate methods for measuring enzyme-catalyzed reaction rate constants, and the use of scanning probe microscopy for imaging and characterization of biological macromolecules.Throughout the course the students will learn how to use computer algebra packages for rigorous data analysis and modeling and will develop the skills in basic electronics, and vacuum techniques. 2 hrs. lec., 6 hrs. lab.
Prerequisites: (09-221 or 09-223) and 09-344

09-323 Bioorganic Chemistry Laboratory

12 units
Bioorganic chemistry is concerned with the action of synthesized compounds on biological systems. In order to maximize the likelihood of identifying a biologically active compound, synthetic libraries are often employed, requiring extensive familiarity with simple, efficient chemical coupling steps and protecting group chemistry. In this inquiry based laboratory course, using a process that mimics the current practice in drug discovery by pharmaceutical companies, students will rationally design a compound library in hopes of finding a compound active against a selected biological target, search for active compounds in the library, and then quantitatively characterize any identified compounds for activity. Working in small groups, students will develop proposals for and execute the target assay selected, the library synthesis, and the screening approach. Students will write reports summarizing the results in each phase of the course. Throughout the course, students will be introduced to concepts relevant to industrial scientific research, including regulatory compliance, quality control and assurance, and intellectual property.
Prerequisites: (09-218 or 09-220) and 09-222

09-325 Special Topics in Chemistry: Environmental Systems on A Changing Planet

All Semesters: 9 units
This course introduces the interconnected Earth systems that regulate our climate and ecosystems, providing the resources required to sustain all life, including human societies. Environmental systems are the fascinating connections between the oceans, atmosphere, continents, ecosystems, and people that provide our planet with resources that all life depends on. Human activities disrupt these natural systems, posing critical threats to the sustainable functioning of environmental systems. The course will explore how solar and biochemical energy moves through the Earth's interconnected systems, recycling nutrients; how complex environmental systems function to produce critical resources such as food and water; and how human activities interfere with environmental systems. Case studies include the interplay between climate change feedbacks, wildfires, and forest ecosystems; the hazards that everyday chemical toxins pose to ecosystems and human health and reproduction; and growing threats to ecosystem health and biodiversity. We will also develop the environmental, scientific, and information literacy required to understand current environmental issues that are frequently debated in the public sphere. This course draws on principles learned in high school science and satisfies the science requirement for the interdisciplinary Minor in Environmental and Sustainability Studies.

09-331 Modern Analytical Instrumentation

Fall: 9 units
This course will cover all aspects of analytical instrumentation and its application to problems in materials, environmental, and biological chemistry. Topics covered will include mass spectrometry, optical spectroscopies and NMR. In addition, the course will emphasize how to select an analytical method appropriate to the problem at hand, how to optimize the signal to noise obtained by a measurement, and the quantitative analysis of experimental data. Some basic electronics will be covered as well. 3 hrs. lec.
Prerequisites: (09-221 or 09-223 or 09-207) and (33-121 or 33-151 or 33-141)

09-344 Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry

Fall: 9 units
We will connect your qualitative understanding of atoms and molecules to a more quantitative treatment, so that each of you can independently assess the extent to which chemistry is based on fundamental principles. To do this we must study the basic principles of quantum theory, because atoms and molecules are quantum particles. These principles influence every aspect of how you think of chemistry and the course will challenge you to think in different ways about the stuff around you. Throughout the course we shall apply quantum principles to develop an understanding of molecular and atomic spectroscopy, and a concurrent understanding of how spectroscopy can be used to learn about the microscopic properties of atoms and molecules. 3 hrs. lec., 1 hr. rec.
Prerequisites: (09-105 or 09-107) and (33-121 or 33-151 or 33-106 or 33-111 or 33-141)

09-345 Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry

Spring: 9 units
The measurement and theoretical descriptions of the equilibrium properties of chemical systems are presented. Chemical thermodynamics is introduced at the upper division level. The phases of matter are discussed. The quantitative treatment of mixtures is developed. The detailed description of chemical equilibrium is elaborated. The measurement and theoretical description of the nonequilibrium properties of chemical systems are presented. Elementary transport properties are introduced. The principles of classical chemical kinetics are developed in great detail. 3 hrs. lec., 1 hr. rec.
Prerequisites: (09-106 or 09-107) and (21-259 or 09-231)

09-348 Inorganic Chemistry

Spring: 10 units
The focus of this class is understanding the properties of the elements and of the inorganic compounds. The electronic structure of elements is discussed as the basis for the element's organization in the Periodic Table and for their properties. We will discuss atomic structure, and bonding of diatomic and polyatomic molecules using different models such as Lewis structures, VSEPR and Molecular Orbital Theory (including group theory and linear combination of atomic orbitals). We will study the structure, spectroscopy, and reactivity of coordination complexes and their application in bioinorganic and organometallic chemistry. 3 hrs. lec., 1 hr. rec.
Prerequisites: (09-107 or 09-105) and 21-120

09-381 Environmental Systems on a Changing Planet

Fall: 12 units
This is 3-unit addendum to the co-requisite 09-291: Environmental Systems on a Changing Planet. These courses introduce the interconnected Earth systems that regulate our climate and ecosystems, providing the resources required to sustain all life and human societies. Please refer to the course description for 09-291 for more information. While 09-291 is designed to be accessible to students from all Colleges and majors, this addendum allows students to engage with the material with more technical depth and quantitative understanding of the function and feedbacks of complex environmental systems. The additional 3-units of 09-381 provides students with an additional weekly meeting time for further material development and discussion, and with additional assignments and exercises on top of 09-291. 09-381 is intended for students from STEM majors in CIT, MCS, and SCS, but can be taken by any student interested in exploring the environmental science topics with greater depth. Science and engineering fundamentals will be further developed and applied to develop the quantitative understanding of the function and feedbacks of complex environmental systems. A background in the natural sciences or engineering (such as introductory-level courses) is strongly recommended for students considering taking 09-381. When taken with 09-291, 09-381 will count as a technical elective for most programs in these STEM colleges, while 09-291 on its own is not considered a technical elective. 09-381 with 09-281 is the correct course for students whose home colleges are CIT, MCS, or SCS. 09-291 is the recommended course for students whose home colleges are CFA, DC, or TBS. 09-381 with 09-291 serve as the foundational Earth and amp; Environmental Science requirement for STEM majors for both the interdisciplinary Minor and Additional Major in Environmental and Sustainability Studies.

09-401 Undergraduate Seminar V

Fall: 1 unit
Students attend seminars on current topics in chemistry. Students are sent a menu of choices for each week of the semester and may select topics of interest. Enrollment is restricted to students majoring in chemistry. 1 hr.

09-402 Undergraduate Seminar VI

Fall and Spring: 3 units
Students enrolled in this course present a 20 - 30 minute oral report on a current topic in chemistry. This may be from the student's research work or a special chemistry topic of general interest. Presentations or papers prepared for other courses are not acceptable for this purpose. Thoroughness in the use of the chemical literature is emphasized. The use of presentation aids such as PowerPoint is required. Other students in the class submit written evaluations of the presentation. Talks are recorded for viewing by the student and instructor as a means of providing individualized feedback about presentation skills. A seminar presentation is required of all chemistry majors. No exceptions possible. Enrollment is limited to students majoring in chemistry. 1 hr.

09-403 Hooked: The Chemical Basis of Drug Addiction

Fall: 9 units
What makes us need something so much that it eclipses other important aspects of our lives, such as family, friends, work, hobbies, health and wellness? There are many different types of addiction; this course will focus on molecular addictions, specifically those involving members of the opiate class of narcotics. The ongoing epidemic of opiate addiction, arising both from over-prescription of pain killers and recreational use of heroin, has been widely reported and continues to rise at alarming rates, ravaging our urban and rural communities. In this course, we will explore the complicated role of chemistry in this epidemic, including the good (elucidating mechanisms of action, development of clinically useful and safe opiates and non-opiate pain killers) and the bad (design and synthesis of increasingly addictive opiates). We will also discuss ethical questions faced by the pharmaceutical industry that develops, markets and sells opiates, the medical community that prescribes opiates, and the government agencies charged with regulating these activities. Students who complete this course will emerge with a broad understanding and perspective on an issue that is of great scientific and societal importance. 3 hrs. lec.
Prerequisites: 09-218 or 09-220

09-425 Special Topics in Chemistry:Environmental Exposure and Risk Assessment

All Semesters: 9 units
Our world is full of synthetic and naturally occurring toxic chemicals, presenting an imminent but difficult-to-quantify threat for human and ecosystem health. In this papers-based course we will ask the question, "How do we decide what's 'safe'?" in the context of exposure and risk assessment for toxic environmental pollutants. We will complete a series of case studies featuring current and seminal literature, in-class activities, and project-based assignments. Each case study will focus on a distinct contaminant exposure scenario and will be linked back to the common theme of using chemistry to understand how external exposure leads to internal dose and subsequent health impacts for diverse environmental pollutants. We will discuss how knowledge generated in the laboratory can be translated and used to inform regulatory decisions. The first half of the course will focus on contaminant bioavailability, exposure, and toxic effects in aquatic organisms. In the second half of the course, we will discuss human exposure to toxic pollutants and strategies to assess risks in the human population, including the human exposome concept, -omics-based research, and strategies for discovering novel harmful contaminants.
Prerequisites: (09-106 or 09-107) and (09-217 or 03-232 or 09-219 or 03-231)

09-435 Independent Study Chemistry

All Semesters
The course allows students to earn academic credit for concentrated study in a topic area developed in conjunction with and monitored by a faculty member in the Department of Chemistry. These topics are distinct from projects that would rise to the level of undergraduate research either because they are in unrelated areas distinct from the faculty member's research interests or may constitute the investigation and compilation of existing information from a variety of resources and may not be expected to result in the generation of new information as is a reasonable expected outcome in undergraduate research (likely is not publishable).

09-445 Undergraduate Research

Fall and Spring
Properly qualified students may undertake research projects under the direction of members of the faculty, normally 6 to 12 hrs/week. A written, detailed report describing the project and results is required. Course may be taken only with the consent of a faculty research advisor in chemistry or on occasion in another department provided that the project is chemical in nature and with permission of the Director of Undergraduate Studies. The number of units taken generally corresponds to the actual number of hours the student actually spends in the lab doing research during the week. Maximum number of units taken per semester is 18.

09-455 Honors Thesis

Fall and Spring
Students enrolled in the departmental honors program (B.S. with Departmental Honors or combined 4-year B.S./M.S. degree) are required to enroll in this course to complete the honors degree requirements. A thesis written in an acceptable style describing an original research project, and a successful oral defense of the thesis topic before a THesis Committee are required. Limited to students accepted into the honors program. (B.S. Honors candidates normally enroll for 6 units; B.S./M.S. candidates enroll for 15 units.)

09-502 Organic Chemistry of Polymers

Spring: 9 units
A study of the synthesis and reactions of high polymers. Emphasis is on practical polymer preparation and on the fundamental kinetics and mechanisms of polymerization reactions. Topics include: relationship of synthesis and structure, step-growth polymerization, chain-growth polymerization via radical, ionic and coordination intermediates, copolymerization, discussions of specialty polymers and reactions of polymers. 09-509, Physical Chemistry of Macromolecules, is excellent preparation for this course but is not required. 3-6 hrs. lec. (Graduate Course: 12 units, 09-741)
Prerequisites: 09-220 or 09-218

09-507 Nanoparticles

Intermittent: 9 units
This course discusses the chemistry, physics, and biology aspects of several major types of nanoparticles, including metal, semiconductor, magnetic, carbon, and polymer nanostructures. For each type of nanoparticles, we select pedagogical examples (e.g. Au, Ag, CdSe, etc.) and introduce their synthetic methods, physical and chemical properties, self assembly, and various applications. Apart from the nanoparticle materials, other topics to be briefly covered include microscopy and spectroscopy techniques for nanoparticle characterization, and nanolithography techniques for fabricating nano-arrays. The course is primarily descriptive with a focus on understanding major concepts (such as plasmon, exciton, polaron, etc.). The lectures are power point presentation style with sufficient graphical materials to aid students to better understand the course materials. Overall, this course is intended to provide an introduction to the new frontiers of nanoscience and nanotechnology. Students will gain an understanding of the important concepts and research themes of nanoscience and nanotechnology, and develop their abilities to pursue highly disciplinary nanoscience research. The course should be of interest and accessible to advanced undergraduates and graduate students in fields of chemistry, materials science, and biology. 3 hrs. lec.

09-509 Physical Chemistry of Macromolecules

Fall: 9 units
This course develops fundamental principles of polymer science. Emphasis is placed on physio-chemical concepts associated with the macromolecular nature of polymeric materials. Engineering aspects of the physical, mechanical and chemical properties of these materials are discussed in relation to chain microstructure. Topics include an introduction to polymer science and a general discussion of commercially important polymers; molecular weight; condensation and addition synthesis mechanisms with emphasis on molecular weight distribution; solution thermodynamics and molecular conformation; rubber elasticity; and the rheological and mechanical properties of polymeric systems. (This course is also listed as 09-715, 12 units) 3 hrs. lec.
Prerequisites: 09-345 or 06-310

09-510 Chemistry and Sustainability

Spring: 9 units
This course aims to educate students in the foundations of systematic leadership for building a sustainable world. Many sustainability challenges are associated with commercial chemicals and with operational modes of the chemical enterprise. For scientists, effectiveness in solving the technical challenges and redirecting cultural behavior is the defining substance of sustainability leadership. The course aims to challenge students to analyze and understand the root causes of unsustainability, especially in the technological and cultural dimensions of the chemical enterprise, to imagine a more sustainable world and to begin to define personal leadership missions. Students will be introduced to sustainability ethics as the foundation stone of transformative sustainability leadership, to the Collins Code of Sustainability Ethics and to other guiding tools. The Collins Bookcase of Green Science Challenges organizes the technical content. It systematizes the major chemical sustainability challenges of our time: clean synthesis, renewable feed-stocks, safe energy, elemental pollutants, persistent molecular toxicants and endocrine disruptors. Focal areas will be the technical, toxicological and cultural histories of elemental and molecular pollutants and endocrine disruptor (ED) science. EDs represent the single greatest sustainability challenge of everyday chemicals all while we are just beginning to recognize an emerging threat to health and the environment from micro- and nano-plastics which are finding their way into human tissues. The course is intended for upper level undergraduates and graduates, although many brilliant freshmen have thrived in the course. The class is limited to 25 students. The assignments are common to both undergraduate and graduate classes offerings with graduates taking additional assignments. (Undergraduate course 9 units 09-510. Graduate course 12 units 09-710) 3 hrs. lec.

09-517 Organotransition Metal Chemistry

Intermittent: 9 units
The first half of this course focuses on the fundamentals of structure and bonding in organotransition metal complexes and how the results can be used to explain, and predict, chemical reactivity. The latter half of the course covers applications, and more specifically, homogeneous catalysts for industrial processes and organic synthesis. (Graduate Course: 12 units, 09-717)
Prerequisite: 09-348

09-518 Bioorganic Chemistry: Nucleic Acids and Carbohydrates

Fall: 9 units
This course will introduce students to new developments in chemistry and biology, with emphasis on the synthesis, structural and functional aspects of nucleic acids and carbohydrates, and their applications in chemistry, biology and medicine. Later in the course, students will have the opportunity to explore cutting-edge research in this exciting new field that bridges chemistry with biology. Students will be required to keep abreast of the current literature. In addition to standard homework assignments and examinations, students will have the opportunity to work in teams to tackle contemporary problems at the forefront of chemistry and biology. The difference between the 09-518 (9-unit) and 09-718 (12-unit) is that the latter is a graduate level course. Students signed up for 09-718 will be required to turn in an original research proposal at the end of the course, in addition to all the other assignments. (Graduate Course: 12 units, 09-718) 3 hrs. lec.
Prerequisites: (03-121 or 03-151) and (09-220 or 09-218)

09-519 Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry

Spring: 9 units
This course will introduce students to new developments in chemistry and biology, with emphasis on the synthesis, structural and functional aspects of peptides, proteins and small molecules. Basic concepts of bioorganic chemistry will be presented in the context of the current literature and students will have the opportunity to learn about the experimental methods used in various research labs. An introduction to combinatorial chemistry in the context of drug design and drug discovery will also be presented. Students will be required to keep abreast of the current literature. Homeworks and team projects will be assigned on a regular basis. The homework assignments will require data interpretation and experimental design; and team projects will give students the opportunity to work in teams to tackle contemporary problems at the interface of chemistry and biology. Students enrolled in the graduate level course (09-719) will be required to turn in an original research proposal at the end of the course, in addition to the homework assignments, midterm, and final exam that are required for the undergraduate course. (Graduate Course: 12 units 09-719) 3 hrs. lec.
Prerequisites: (03-151 or 03-121) and (09-218 or 09-220)

09-521 Metals in Biology: Function and Reactivity

Intermittent: 6 units
Metal ions play important roles in many biological processes, including photosynthesis, respiration, global nitrogen cycle, carbon cycle, antibiotics biosynthesis, gene regulation, bio-signal sensing, and DNA/RNA repair, just to name a few. Usually, metal ions are embedded in protein scaffold to form active centers of proteins in order to catalyze a broad array of chemical transformations, which are essential in supporting the biological processes mentioned above. These metal containing proteins, or metalloproteins, account for half of all proteins discovered so far. In this course, the relation between the chemical reactivity and the structure of metalloproteins will be discussed in detail. The main focus is to illustrate the geometric and electronic structure of metal centers and their interactions with the protein environment in governing the chemical reactivity of metalloproteins. The applications of these principles in designing biomimetic/bioinspried inorganic catalysts and in engineering metalloproteins bearing novel chemical reactivity will also be discussed. The basic principles of the frequently utilized physical methods in this research area will also be introduced, which include optical absorption spectroscopy, Infrared (IR) and Raman spectroscopies, M and #246;ssbauer spectroscopy, electron paramagnetic resonance (EPR), X-ray absorption and diffraction techniques.
Prerequisites: (09-344 or 09-345 or 09-214 or 09-347) and 09-348

09-522 Kinetics and Mechanisms of Chemical and Enzymatic Reactions

Intermittent: 9 units
This is a practical course aimed at learning the major modern tools which are essential for investigation of mechanisms of homogeneous chemical and enzymatic reactions. Rules of formal chemical kinetics in solution are first considered followed by basic principles of kinetics of enzymatic processes including inhibition, which is a key factor in the up-to-date drug design. The relationships between electronic structures, catalytic properties, and reactivity of biologically relevant metal complexes will be provided. Electrochemical and redox features of metal complexes will be reviewed. The course includes such hot topics as Fenton chemistry, Marcus's electron transfer concept, catalysis by Collins' TAML activators of peroxides, specific and general acid/base, proximal and micellar catalysis. Mechanistic pathways of action of hydrolases, kinases, hydrogenases, oxidases, peroxidases, cytochrome P-450, and other metalloenzymes will be described. The course is supplied by the recently published text (A. D. Ryabov "Practical Kinetics and Mechanisms of Chemical and Enzymatic Reactions" Cambridge Scholars Publishing, Newcastle upon Tyne, NE6 2PA, UK) which includes all the above mentioned themes (Graduate course: 09-722, 12-units) 3 hrs. lec. Prerequisite: 09-348
Prerequisite: 09-348

09-524 Environmental Chemistry

Spring: 9 units
Environmental pollutants are common consequences of human activities. These chemicals have a wide range of deleterious effects on the environment and people. This course will introduce students to a range of major environmental pollutants, with a particular focus on persistent organic pollutants. We will use chemical principles including thermodynamics, kinetics, photochemistry, organic reaction mechanisms, and structure-activity relationships to understand the environmental fate of major classes of pollutants. The transport of chemicals through the environment and their partitioning between air, water, soil, and people will be described. The major environmental reaction pathways (oxidation, photolysis, hydrolysis, reduction, metabolism) of common pollutants will be explored. This will provide students with the necessary knowledge to predict the chemical fate of environmental pollutants, and improve their understanding of the environmental impacts of their everyday chemical use and exposure. Specific topics include water quality, photochemical smog, organic aerosols, atmospheric chemistry and global climate change, toxicity of pesticides, and heterogeneous and multiphase atmospheric chemistry. The 12-unit course is intended for graduate students that want to explore aspects of the course more deeply. This includes additional requirements including a final term paper and in-class presentation, and additional advanced questions on the homework assignments.
Prerequisites: 09-219 or 09-217

09-525 Transition Metal Chemistry

Intermittent: 9 units
This class is focused understanding the structure, spectroscopy and reactivity of 3d metal complexes. Based on ligand field theory, we will analyze the electronic structure of these metal complexes and we will briefly describe the main spectroscopic techniques that will allow for studying this topic (X-ray diffraction analysis, UV-vis, EPR, NMR, EXAFS and Mossbauer). The main focus of the course will be on analyzing the reactivity of 3d metal complexes in the context of metalloenzymes and small-molecule bioinspired complexes. The natural and synthetic metal complexes involved in O2 reduction, H2O oxidation, N2 reduction, H2 formation and functionalization of organic molecules (e.g. hydroxylation of C-H bonds, dehydrogenation of alcohols, etc.), and the reaction pathways by which these important processes take place will be studied in detail. (Graduate Course: 12 units, 09-725) 3 hrs. lec.
Prerequisite: 09-348

09-529 Introduction to Sustainable Energy Science

Fall: 9 units
This course focuses on the chemistry aspects of sustainable energy science. It introduces the major types of inorganic and molecular materials for various important processes of energy conversion and storage, such as photovoltaics, fuel cells, water splitting, solar fuels, batteries, and CO2 reduction. All the energy processes heavily rely on innovations in materials. This course is intended to offer perspectives on the materials/physical chemistry that are of importance in energy processes, in particular, how the atomic and electronic structures of materials impact the energy harvesting and conversion. In current energy research, intense efforts are focused on developing new strategies for achieving sustainable energy through renewable resources as opposed to the traditional oil/coal/gas compositions. This course offers students an introduction to the current energy research frontiers with a focus on solar energy conversion/ storage, electrocatalysis and artificial photosynthesis. The major types of materials to be covered include metals, semiconductors, two-dimensional materials, and hybrid perovskites, etc. The material functions in catalysis, solar cells, fuel cells, batteries, supercapacitors, hydrogen production and storage are also discussed in the course. The lectures are power-point presentation style with sufficient graphical materials to aid students to better understand the course materials. Demo experiments are designed to facilitate student learning.
Prerequisites: (09-107 or 09-105) and (33-121 or 33-141 or 33-151)

09-530 Chemistry of Gene Expression

Fall: 9 units
This course examines the chemical basis of biological reactions required for the propagation of genetic information stored in DNA and the organic chemistry principles behind the structure and function of nucleic acids.Main topics of lectures and class discussion will include the chemical and biochemical syntheses, properties and analyses of natural and modified nucleic acids to investigate cellular processes such as transcription, RNA splicing, other RNA regulation and translation; an introduction to the enzymatic strategies that accelerate these chemical reactions and a comparison of protein enzymes, ribozymes and other nucleic acid based enzymes in contemporary chemistry and biology. Students will learn to critically evaluate current scientific efforts that examine various aspects of chemistry and biological chemistry, the relationship between the structure and function of biomolecular systems, propose experiments to examine biological chemistry research problems and communicate these ideas and participate in scientific discussions and debates. 3 hrs. lec.

09-531 Polymer Science

Fall: 9 units
Polymer science is a vibrant multidisciplinary activity. It uses the methods of chemistry, physics, chemical engineering, materials science and biology to create a coherent picture of the macromolecular world. This course is a survey of this field of endeavor suitable for Senior chemistry majors, or other students with a desire for a broad knowledge of the science and engineering of polymers. It covers a thorough description of the field, the synthetic chemistry of macromolecules, the physical chemistry of macromolecules, and the principles of polymer engineering and processing.
Prerequisites: (09-219 or 09-217) and (09-214 or 09-345 or 09-347)

09-534 Environmental Chemistry

Spring: 9 units
Solar energy and electrical energy from renewable resources need to be stored to resolve intermittency issues. Energy can be stored through charge transfer, changes in chemical bonding, or in electric polarization. This course will introduce students to general aspects of energy-storage technologies using these strategies, integrating scientific and engineering perspectives to discuss thermodynamics, mechanisms of energy storage, and fundamental aspects of efficiency, capacity, and power delivery. Then we will explore current and experimental technologies, covering supercapacitors, batteries, and water-splitting catalysts. By the end of the course, students will be able to apply chemical principles to understand energy-storage technologies and gain knowledge of important classes of these systems. Students enrolled in 09-734 (rather than 09-534) will also be required to write a 15-page NSF style proposal. 3 hrs. lec.
Prerequisites: (09-217 or 09-219) and (09-345 or 09-347 or 24-324 or 27-215 or 33-341)

09-535 Applied topics in Macromolecular and Biophysical Techniques

Fall: 9 units
Applications of physical chemistry are widespread. Physical chemical principles are fundamental to the methods used to sequence human genome, obtain high resolution structures of proteins and complex nucleic acids e.g., ribosome, and further provides the framework to predict how molecules fold in 3-dimension, how the different domains interact (inter- and intra-molecular interactions) to perform biological functions. The principles that were discussed in theory in undergraduate physical chemistry classes, will be applied in order to understand the molecular structures and dynamics in nucleic acids and proteins, and to more advanced molecular motors. In the last decade major advances have been made through single-molecule studies that provide finer details of macromolecules in action. This course aims to teach and apply physical chemistry as related to biological problems.
Prerequisites: (09-345 or 09-214 or 09-347) and (03-121 or 03-231 or 03-232)

09-538 Exposure and Risk Assessment for Environmental Pollutants

All Semesters: 9 units
Our world is full of synthetic and naturally occurring toxic chemicals, presenting an imminent but difficult-to-quantify threat for human and ecosystem health. In this papers-based course we will ask the question, "How do we decide what's 'safe'?" in the context of exposure and risk assessment for toxic environmental pollutants. We will complete a series of case studies featuring current and seminal literature, in-class activities, and project-based assignments. Each case study will focus on a distinct contaminant exposure scenario and will be linked back to the common theme of using chemistry to understand how external exposure leads to internal dose and subsequent health impacts for diverse environmental pollutants. We will discuss how knowledge generated in the laboratory can be translated and used to inform regulatory decisions. The first half of the course will focus on contaminant bioavailability, exposure, and toxic effects in aquatic organisms. In the second half of the course, we will discuss human exposure to toxic pollutants and strategies to assess risks in the human population, including the human exposome concept, -omics-based research, and strategies for discovering novel harmful contaminants.
Prerequisites: 09-105 or 09-107 or 09-106

09-560 Computational Chemistry

Fall: 12 units
Computer modeling is playing an increasingly important role in chemical, biological and materials research. This course provides an overview of computational chemistry techniques including molecular mechanics, molecular dynamics, electronic structure theory and continuum medium approaches. Sufficient theoretical background is provided for students to understand the uses and limitations of each technique. An integral part of the course is hands on experience with state-of-the-art computational chemistry tools running on graphics workstations. This course I can count towards coursework requirements for chemistry PhD candidates. 3 hrs. lec.
Prerequisites: 09-347 or 09-345 or 09-344 or 09-214

09-561 Computational Chemistry

Spring: 9 units
Computer modeling is playing an increasingly important role in chemical, biological and materials research. This course provides an overview of computational chemistry techniques including molecular mechanics, molecular dynamics, electronic structure theory and continuum medium approaches. Sufficient theoretical background is provided for students to understand the uses and limitations of each technique. An integral part of the course is hands on experience with state-of-the-art computational chemistry tools running on graphics workstations. This course I can count towards coursework requirements for chemistry PhD candidates. 3 hrs. lec.

09-563 Molecular Modeling and Computational Chemistry

Spring: 9 units
Computer modeling is playing an increasingly important role in chemical, biological and materials research. This course provides an overview of computational chemistry techniques including molecular mechanics, molecular dynamics, electronic structure theory and continuum medium approaches. Sufficient theoretical background is provided for students to understand the uses and limitations of each technique. An integral part of the course is hands on experience with state-of-the-art computational chemistry tools running on graphics workstations. This course I can count towards coursework requirements for chemistry PhD candidates. 3 hrs. lec.
Prerequisites: 09-347 or 09-344 or 09-214 or 09-345

09-604 Introduction to Chemical Kinetics

Spring: 6 units
Empirical description of the time evolution of chemical reactions. Inductive derivation of kinetic rate laws from actual data. Deductive derivation of kinetic rate laws from proposed mechanisms. Gas phase reactions, catalyzed reactions, enzyme kinetics. Theories of kinetic rate constants for gas phase reactions: unimolecular and bimolecular. Theories of solution phase reactions. Absolute reactions rate theory. Diffusion controlled reactions. Kinetics in highly viscous media. Activation energy and entropy. Volume of activation.

09-611 Chemical Thermodynamics

Fall: 6 units
This course provides an introduction to the general formalism of macroscopic thermodynamics and its applications to chemical systems. The main topics to be covered include: entropy maximum postulate, internal energy minimum postulate, various equilibrium conditions including chemical equilibrium, Legendre transformation and free energies, thermochemistry, phase equilibria and solution systems.
Prerequisites: 09-231 and 09-345

09-614 Spectroscopy

Intermittent: 6 units
This is a course exclusively in optical methods, both time resolved and steady state. In addition to methodology, spectral interpretation in terms of group theory will be discussed. The time-dependent formalism of quantum mechanics will also be introduced. Molecules in gas phase and condensed phase will be discussed. Frequent use will be made of the current literature. Background consisting of undergraduate physical chemistry is assumed. This course has a prerequisite 09-344, Quantum Chemistry or permission of the instructor.

09-615 Computational Modeling, Statistical Analysis and Machine Learning in Science

Fall: 12 units
The purpose of this course is to provide a practical introduction to the core concepts and tools of machine learning in a manner easily understood and intuitive to STEM students. The course begins by covering fundamental concepts in ML, data science, and modern statistics such as the bias-variance tradeoff, overfitting, regularization, and generalization, before moving on to more advanced topics in both supervised and unsupervised learning. Students will choose a large dataset from a selection of biology, chemistry, math, or physics datasets hosted by PSC and use this dataset throughout the MS program. The topics of the course are taught with students analyzing the chosen dataset. An intensive knowledge of Python or another computing language is not a pre-prerequisite since students will be given at first simple scripts that they work with and then expand upon. This course is required for students enrolled in the MS program in Data Analytics for Science.
Prerequisites: (09-344 or 09-231) and (15-110 or 15-112)

09-616 Neural Networks & Deep Learning in Science

Spring: 12 units
Focus on practice and applications of deep learning by exploring foundational concepts, structuring popular networks and implementing models through modern technologies (python, Jupyter notebooks and PyTorch). Other topics may include image recognition, machine translation, natural language processing, parallelism, GPU distributed computing, cloud technologies, inference and parameter tting in deep networks. Course uses large datasets hosted by PSC.

09-621 Welcome to the Future Lab - Science in the Cloud

Fall: 6 units
You can be at home or anywhere in the world and still run experiments in a lab. This course is to introduce and train students in the use of an automated and remote cloud lab facility. Operations in the cloud lab are conducted through a computer console and internet access that allows the user to program equipment, set up experiments and analyze data. In this course, students will learn the steps to use the Wolfram language/ Mathematica based Cloud Lab Command Center interface to remotely interact with the facilities and laboratory instruments in the cloud lab. Following training exercises, students will be able to select the appropriate equipment and reagents to prepare samples and solutions for laboratory analyses and experiments. (No prior knowledge of Mathematica is required but basic programming skills are helpful)

09-623 Future Lab- DNA Science in the Cloud

Fall: 6 units
This course uses an automated and remote cloud lab facility and will involve learning the steps to handle, manipulate and quantitate solutions of DNA and nucleic acids. Students will set up experiments that automate the dispensing, analysis and purification of nucleic acids and use DNA for biophysical measurements. Students will learn to remotely operate, design and execute experiments on state-of-the-art instrumentation to analyze DNA sequence and structure. Besides learning how to remotely use equipment and instruments for synthesis and analyses by spectroscopy and spectrometry, students will also learn about nucleic acids as part of their experiments. (Prior training in the use of the cloud lab is required)
Prerequisite: 09-621 Min. grade C

09-701 Quantum Chemistry I

Fall: 12 units
The main topics to be covered will include exploration of the Schroedinger equation, operators, particle in the box, harmonic oscillator and hydrogen atom, tunneling, Stern-Gerlach experiment and quantum mechanical postulates, time-independent and time-dependent perturbation theory, matrix diagonalization. The student will learn to master the fundamental concepts and techniques of quantum mechanics. The parallel mini course Mathematical Analysis for Chemistry will provide the necessary mathematical background.

09-702 Statistical Mechanics and Dynamics

Intermittent: 12 units
This course will address the application of statistical mechanics to chemical systems. Topics to be discussed include the calculation of thermodynamic functions, phase transitions and chemical equilibrium, calculation of the transport properties of gases and liquids and the elementary theory of chemical kinetics.
Prerequisites: (09-611 or 09-344) and 09-231 and 09-701

09-705 Chemosensors and Biosensors

Intermittent: 12 units
Chemosensors and biosensors rely on "recognition" and "signaling" elements to transduce a molecular-scale binding event into an observable signal. Students in this course will be introduced to current research and technology for detecting chemical and biological analytes in a variety of contexts, including environmental testing, biological probing and medical diagnostics. Recognition elements ranging from small organic molecules to antibodies will be presented, while various detection modes, including fluorescence, gravimetric and colorimetric, that illustrate different signaling elements will be discussed and compared. Issues to be addressed include sensitivity, selectivity and efficiency. Each sensor will be analyzed in terms of the physical chemistry, organic chemistry and/or biochemistry underlying its function. This is a graduate level course that may also be appropriate for upper level undergraduates in chemistry and the biological sciences. The material in 09-518/09-519 or 09-718/09-719 would be appropriate background material for this course. 3 hrs. lec.
Prerequisites: (03-121 or 03-232 or 03-231) and (09-220 or 09-218)

09-707 Nanoparticles

Intermittent: 12 units
This course discusses the chemistry, physics, and biology aspects of several major types of nanoparticles, including metal, semiconductor, magnetic, carbon, and polymer nanostructures. For each type of nanoparticles, we select pedagogical examples (e.g. Au, Ag, CdSe, etc.) and introduce their synthetic methods, physical and chemical properties, self assembly, and various applications. Apart from the nanoparticle materials, other topics to be briefly covered include microscopy and spectroscopy techniques for nanoparticle characterization, and nanolithography techniques for fabricating nano-arrays. The course is primarily descriptive with a focus on understanding major concepts (such as plasmon, exciton, polaron, etc.). The lectures are power point presentation style with sufficient graphical materials to aid students to better understand the course materials. Overall, this course is intended to provide an introduction to the new frontiers of nanoscience and nanotechnology. Students will gain an understanding of the important concepts and research themes of nanoscience and nanotechnology, and develop their abilities to pursue highly disciplinary nanoscience research. 3 hrs. lec.

09-710 Chemistry and Sustainability

Spring: 12 units
This course aims to educate students in the foundations of systematic leadership through chemistry and more for building a sustainable world. Many sustainability challenges are associated with commercial chemicals and with operational modes of the chemical enterprise. The course aims to challenge students to analyze and understand the root causes of unsustainability, especially in the technological dimension, to imagine a more sustainable world and to begin to define personal leadership missions. Students will be introduced to sustainability ethics as the foundation of transformative sustainability leadership, to a sustainability compass, to a Code of Sustainability Ethics and to various other helpful conceptual material as tools for analyzing the reasons our civilization has been failing to address its own unsustainability. The Collins Bookcase of Green Science Challenges organizes the technical content. It systematizes the major chemical sustainability challenges of our time: clean synthesis, renewable feed-stocks, safe energy, elemental pollutants, persistent molecular toxicants and endocrine disrupting chemicals (EDCs). Focal areas will be the technical, toxicological and cultural histories of elemental and molecular pollutants with particular emphasis on EDCs. Students will experience Legacy Lectures from some of the world's leading endocrine disruption scientists. The graded substance will take the form of take-home work. Students will primarily watch classic movies and read key books and articles and will summarize and personally evaluate the material in essay assignments. The course is intended for upper-level undergraduates and graduates although it is open to all students. The class is limited to 30 students. The assignments are common to both undergraduate and graduate classes offerings and 09-710 students will engage in additional projects. 3 hrs. lec.
Prerequisites: 09-107 or 09-105

09-711 Physical Organic Chemistry

Fall: 12 units
This course introduces students to the study of structure and reactivity of organic compounds from a physical and theoretical standpoint. Students will learn the fundamentals of molecular orbital theory along with some practical applications to aromaticity and anti-aromaticity. Methods are described for the study of reaction mechanisms by means of physical methods such as kinetics, isotope effects, substituent effects, and solvent effects. Important reactive intermediates are described, along with detection methods. This course may be suitable for upper level undergraduates in chemistry with the appropriate background in organic chemistry and physical chemistry. 3 hrs. lec.
Prerequisites: (09-220 or 09-218) and (09-347 or 09-344)

09-714 Advanced Organic Chemistry

Spring: 12 units
This course will expose the students to modern methods of organic synthesis including insights into the basis and mechanisms of chemical reactions. Topics include but are not limited to: modern spectroscopic analysis and structure determination, synthetic methods, retrosynthesis, organic reaction mechanisms, and references to separation techniques and some analytical methods. Upon completion of the course students should be able to design reaction schemes using scientific literature sources, evaluate their suitability for use in the lab and develop an aptitude in identifying the use of modern reagents that are more efficient, specific, safer and environmentally friendly. It is assumed that at minimum students will have completed at least two semesters of undergraduate coursework in organic chemistry and suggested that they have completed 09-222 and 09-321, the organic laboratory courses. 3 hrs. lec
Prerequisites: 09-220 or 09-218

09-715 Physical Chemistry of Macromolecules

All Semesters: 12 units
This course addresses the fundamentals of polymer science with the emphasis on physicochemical consequences of chain nature of macromolecules and on the behavior of polymers in condensed state (polymers as soft condense matter). The topics to be covered include: chain structure and molecular weight; molecular weight distribution; step growth and addition polymerization mechanisms; chain conformation and behavior of polymers in solution; concentrated solutions and phase separation behavior; rubber elasticity; introduction to polymer viscoelasticity and rheology; mechanical behavior of polymers; glass transition and crystallization; multicomponent polymeric materials; liquid crystalline polymers; polymers at surfaces and interfaces; self-assembly and nanostructure formation in synthetic and biological systems; conducting and semiconducting polymers. Graduate students taking the course for 12 units will be required to write a term paper on a selected topic. 3 hrs. lec.
Prerequisites: 06-310 or 09-345

09-716 Bioactive Natural Products

Spring: 12 units
This course is aimed at students with an interest in natural products research. Natural products are used as active components in medicinal products, as model compounds for further development into medicinally active drugs, as ingredients in food and for flavor and fragrances, among other very useful and interesting applications. An overview of the structural variety and activity of natural products will be presented along with their isolation and structural determination. Overall, the course will offer an introduction to the work that is customary in natural product research. This course will cover: Strategies to select the plant or marine material for study; main groups of natural products derived from plants; representative natural products derived from marine organisms; preparation of extracts and selection of active fractions, screening strategies; separation and purification of active components; bench-top bioassays and chemical assays and structure elucidation (especially 2D-NMR spectroscopy) Student's performance will be assessed by weekly assignments on the topics discussed in lecture and exams. 3 hrs. lec.
Prerequisites: 09-219 or 09-217

09-718 Bioorganic Chemistry: Nucleic Acids and Carbohydrates

Fall: 12 units
This course will introduce students to new developments in chemistry and biology, with emphasis on the synthesis, structural and functional aspects of nucleic acids and carbohydrates, and their applications in chemistry, biology and medicine. Later in the course, students will have the opportunity to explore cutting-edge research in this exciting new field that bridges chemistry with biology. Students will be required to keep abreast of the current literature. In addition to standard homework assignments and examinations, students will have the opportunity to work in teams to tackle contemporary problems at the forefront of chemistry and biology. The difference between the 09-518 (9-unit) and 09-718 (12-unit) is that this latter is a graduate level course. Students signed up for 09-718 will be required to turn in an original research proposal at the end of the course, in addition to all the other assignments. 3 hrs. lec.
Prerequisites: (03-121 or 03-151) and (09-220 or 09-218)

09-719 Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry

Spring: 12 units
This course will introduce students to new developments in chemistry and biology, with emphasis on the synthesis, structural and functional aspects of peptides, proteins and small molecules. Basic concepts of bioorganic chemistry will be presented in the context of the current literature and students will have the opportunity to learn about the experimental methods used in various research labs. An introduction to combinatorial chemistry in the context of drug design and drug discovery will also be presented. Students will be required to keep abreast of the current literature. Homeworks and team projects will be assigned on a regular basis. The homework assignments will require data interpretation and experimental design; and team projects will give students the opportunity to work in teams to tackle contemporary problems at the interface of chemistry and biology. Students enrolled in the graduate level course (09-719) will be required to turn in an original research proposal at the end of the course, in addition to the homework assignments, midterm, and final exam that are required for the undergraduate course.
Prerequisites: (03-121 or 03-151) and (09-218 or 09-220)

09-720 Physical Inorganic Chemistry

Intermittent: 6 units
This course develops the principles of magnetochemistry and inorganic spectroscopy. Electronic absorption, magnetic circular dichroism, resonance raman, NMR, EPR, Mossbauer, magnetization and x-ray methods will be introduced with application towards the determination of electronic structures of transition metal complexes.
Prerequisites: 09-344 and 09-348 and 09-345

09-721 Metals in Biology: Function and Reactivity

Intermittent: 6 units
Metal ions play important roles in many biological processes, including photosynthesis, respiration, global nitrogen cycle, carbon cycle, antibiotics biosynthesis, gene regulation, bio-signal sensing, and DNA/RNA repair, just to name a few. Usually, metal ions are embedded in protein scaffold to form active centers of proteins in order to catalyze a broad array of chemical transformations, which are essential in supporting the biological processes mentioned above. These metal containing proteins, or metalloproteins, account for half of all proteins discovered so far. In this course, the relation between the chemical reactivity and the structure of metalloproteins will be discussed in detail. The main focus is to illustrate the geometric and electronic structure of metal centers and their interactions with the protein environment in governing the chemical reactivity of metalloproteins. The applications of these principles in designing biomimetic/bioinspried inorganic catalysts and in engineering metalloproteins bearing novel chemical reactivity will also be discussed. The basic principles of the frequently utilized physical methods in this research area will also be introduced, which include optical absorption spectroscopy, Infrared (IR) and Raman spectroscopies, M and #246;ssbauer spectroscopy, electron paramagnetic resonance (EPR), X-ray absorption and diffraction techniques.
Prerequisites: (09-344 or 09-214 or 09-347 or 09-345) and 09-348

09-722 Kinetics and Mechanisms of Chemical and Enzymatic Reactions

Intermittent: 12 units
This is a practical course aimed at learning the major modern tools which are essential for investigation of mechanisms of homogeneous chemical and enzymatic reactions. Rules of formal chemical kinetics in solution are first considered followed by basic principles of kinetics of enzymatic processes including inhibition, which is a key factor in the up-to-date drug design. The relationships between electronic structures, catalytic properties, and reactivity of biologically relevant metal complexes will be provided. Electrochemical and redox features of metal complexes will be reviewed. The course includes such hot topics as Fenton chemistry, Marcus's electron transfer concept, catalysis by Collins' TAML activators of peroxides, specific and general acid/base, proximal and micellar catalysis. Mechanistic pathways of action of hydrolases, kinases, hydrogenases, oxidases, peroxidases, cytochrome P-450, and other metalloenzymes will be described. The course is supplied by the recently published text (A. D. Ryabov "Practical Kinetics and Mechanisms of Chemical and Enzymatic Reactions" Cambridge Scholars Publishing, Newcastle upon Tyne, NE6 2PA, UK) which includes all the above mentioned themes (Graduate course: 09-722, 12-units) 3 hrs. lec. Prerequisite: 09-348
Prerequisites: 09-345 and 09-220 and 09-348

09-723 Proximal Probe Techniques: New Tools for Nanoscience & Nanotechnology

Intermittent: 12 units
Proximal probe techniques are revolutionizing physical and biological sciences, owing to their ability to explore and manipulate matter at the nanoscale, and to operate in various environments (including liquids). Proximal probe techniques rely on the use of nanoscale probes, positioned and scanned in the immediate vicinity of the material surface. Their development is often viewed as a first step towards nanotechnology, since they demonstrate the feasibility of building purposeful structures one atom or one (macro)molecule at a time. This course is designed for the students of chemistry, biology physics and engineering, who are interested in the fundamentals of proximal probe techniques and in their applications in various areas, converging into a rapidly developing, interdisciplinary field of nanoscience. It will provide physical background of such basic techniques as Atomic Force Microscopy (AFM), Scanning Tunneling Microscopy (STM), and Near-Field Scanning Optical Microscopy (NSOM) and of their variants. Throughout the course, the working "virtual AFM" computer model will be assembled in classroom by each student and then used extensively to gain thorough understanding of AFM operation principles. Particular emphasis will be placed on modes of operation facilitating chemical contrast and contrast based on other material properties. (No prior experience with computer programming required). 3 hrs. lec.
Prerequisites: (21-124 or 21-122 or 09-231) and (09-344 or 09-331 or 09-322 or 09-345)

09-724 Environmental Chemistry

Spring: 12 units
Environmental pollutants are common consequences of human activities. These chemicals have a wide range of deleterious effects on the environment and people. This course will introduce students to a range of major environmental pollutants, with a particular focus on persistent organic pollutants. We will use chemical principles including thermodynamics, kinetics, photochemistry, organic reaction mechanisms, and structure-activity relationships to understand the environmental fate of major classes of pollutants. The transport of chemicals through the environment and their partitioning between air, water, soil, and people will be described. The major environmental reaction pathways (oxidation, photolysis, hydrolysis, reduction, metabolism) of common pollutants will be explored. This will provide students with the necessary knowledge to predict the chemical fate of environmental pollutants, and improve their understanding of the environmental impacts of their everyday chemical use and exposure. Specific topics include water quality, photochemical smog, organic aerosols, atmospheric chemistry and global climate change, toxicity of pesticides, and heterogeneous and multiphase atmospheric chemistry. This 12-unit course is intended for graduate students that want to explore aspects of the course more deeply. This includes additional requirements including a final term paper and in-class presentation, and additional advanced questions on the homework assignments. Undergraduates should register for 09-524, the 9-unit version of the class, unless they obtain specific permission from the instructor to enroll in this class.
Prerequisites: 09-217 or 09-219

09-729 Introduction to Sustainable Energy Science

Fall: 12 units
This course focuses on the chemistry aspects of sustainable energy science. It introduces the major types of inorganic and molecular materials for various important processes of energy conversion and storage, such as photovoltaics, fuel cells, water splitting, solar fuels, batteries, and CO2 reduction. All the energy processes heavily rely on innovations in materials. This course is intended to offer perspectives on the materials/physical chemistry that are of importance in energy processes, in particular, how the atomic and electronic structures of materials impact the energy harvesting and conversion. In current energy research, intense efforts are focused on developing new strategies for achieving sustainable energy through renewable resources as opposed to the traditional oil/coal/gas compositions. This course offers students an introduction to the current energy research frontiers with a focus on solar energy conversion/ storage, electrocatalysis and artificial photosynthesis. The major types of materials to be covered include metals, semiconductors, two-dimensional materials, and hybrid perovskites, etc. The material functions in catalysis, solar cells, fuel cells, batteries, supercapacitors, hydrogen production and storage are also discussed in the course. The lectures are power-point presentation style with sufficient graphical materials to aid students to better understand the course materials. Demo experiments are designed to facilitate student learning.
Prerequisites: (09-105 or 09-107) and (33-151 or 33-121 or 33-141)

09-730 Chemistry of Gene Expression

Fall: 12 units
rinciples behind the structure and function of nucleic acids.Main topics of lectures and class discussion will include the chemical and biochemical syntheses, properties and analyses of natural and modified nucleic acids to investigate cellular processes such as transcription, RNA splicing, other RNA regulation and translation; an introduction to the enzymatic strategies that accelerate these chemical reactions and a comparison of protein enzymes, ribozymes and other nucleic acid based enzymes in contemporary chemistry and biology. Students will learn to critically evaluate current scientific efforts that examine various aspects of chemistry and biological chemistry, the relationship between the structure and function of biomolecular systems, propose experiments to examine biological chemistry research problems and communicate these ideas and participate in scientific discussions and debates. 3 hrs. lec.

09-732 Biocatalysis: Fundamentals, Recent Advances and Industrial Applications

Fall: 6 units
Biocatalysis is a rapidly developing field that utilizes naturally evolved and bioengineered enzymes as platforms to offer revolutionary solutions for chemical production. Modern biocatalysis relies on enzyme discovery, enzyme reaction mechanism elucidation, and high throughput screening processes for enzyme bioengineering. The recent established world's first academic cloud lab at CMU is a perfect remote-access and automated facility to be used to expand our research capacity into the biocatalysis area in both fundamental studies and biocatalytic platform development and engineering. This great research and educational opportunity calls for the development of courses to disseminate fundamental knowledge and practical skills related to biocatalysis to students so that the interested students could start engaging in this area of research. Thus, this proposed course, with the aim to introduce the field of biocatalysis in both academic studies and industrial applications, starts filling this gap. This course features an in-depth discussion of different topics in biocatalysis with examples of how biocatalysis has reshaped various aspects of modern industries including food, pharmaceuticals, consumer products and biomaterials industries. This course also provides an overview of common enzyme classes used in modern biocatalysis and their associated catalytic mechanisms and engineering. Hands-on experience of common bioinformatic and computational tools for new enzyme discovery will also be integrated into the course.
Prerequisites: (09-219 or 09-217) and (03-231 or 03-151 or 03-121 or 03-232)

09-736 Transition Metal Catalysis for Organic and Polymer Synthesis

Intermittent: 12 units
Transition metal catalysts are invaluable in small molecule and polymer synthesis. The course will begin with a brief overview of organometallic chemistry and a discussion of fundamental organometallic reactions. Following this, a survey of some selected topics for the formation of small molecules and polymers will be presented. Some topics to be highlighted include: (1) Hydrogenation (2) Palladium Catalyzed Cross-Coupling (3) Epoxidation (4) Olefin Metathesis (5) Olefin Polymerization
Prerequisites: (09-218 or 09-220) and 09-348

09-737 Medicinal Chemistry and Drug Development

Spring: 12 units
Organic chemistry is an intimate part of the drug discovery and design processes in areas that include structure determination (NMR, mass spectrometry), synthesis, and determination of mechanisms of action. Once a promising compound (i.e. a ?lead?) has been identified in the laboratory, it is rarely ready to be used in the clinic. Complications include poor bioavailability, rapid degradation, and off-target effects. Students will learn about lead compound optimization through structural variations, cell-specific targeting and pro-drug strategies. Several examples will be presented to illustrate the role played by organic chemistry in the development of drugs used to treat a range of diseases, including cancer, HIV-AIDS, bacterial infections and heart disease.
Prerequisites: 09-220 or 09-218

09-738 Exposure and Risk Assessment for Environmental Pollutants

Intermittent: 12 units
Our world is full of synthetic and naturally occurring toxic chemicals, presenting an imminent but difficult-to-quantify threat for human and ecosystem health. In this papers-based course we will ask the question, "How do we decide what's 'safe'?" in the context of exposure and risk assessment for toxic environmental pollutants. We will complete a series of case studies featuring current and seminal literature, in-class activities, and project-based assignments. Each case study will focus on a distinct contaminant exposure scenario and will be linked back to the common theme of using chemistry to understand how external exposure leads to internal dose and subsequent health impacts for diverse environmental pollutants. We will discuss how knowledge generated in the laboratory can be translated and used to inform regulatory decisions. The first half of the course will focus on contaminant bioavailability, exposure, and toxic effects in aquatic organisms. In the second half of the course, we will discuss human exposure to toxic pollutants and strategies to assess risks in the human population, including the human exposome concept, -omics-based research, and strategies for discovering novel harmful contaminants.
Prerequisites: 09-107 or 09-106 or 09-105

09-741 Organic Chemistry of Polymers

Spring: 12 units
A study of the synthesis and reactions of high polymers. Emphasis is on practical polymer preparation and on the fundamental kinetics and mechanisms of polymerization reactions. Topics include: relationship of synthesis and structure, step-growth polymerization, chain-growth polymerization via radical, ionic and coordination intermediates, copolymerization, discussions of specialty polymers and reactions of polymers. Students in 09-741 will take the same lectures and the same exams as those enrolled in 09-502 but, in addition, will prepare a term paper on the topic of advanced polymeric materials, to be approved by the instructor. 09-509 or 09-715, Physical Chemistry of Macromolecules, is excellent preparation for this course but is not required. 3-6 hrs. lec.

09-760 The Molecular Basis of Polymer Mechanics

Spring: 12 units
This course is a graduate level course designed to prepare students for graduate research in polymer science. Based around a laboratory component, students will learn the lab skills needed to synthesize and fully characterize novel polymer materials. The classroom component will teach the theory behind the measurements made in lab, as well as an understanding of the best experiments to learn about the properties of the material. Emphasis will be placed on current literature and technical communication (written and oral). 3 hrs lec; 3 hrs lab

09-763 Molecular Modeling and Computational Chemistry

Spring: 12 units
Computer modeling is playing an increasingly important role in chemical, biological and materials research. This course provides an overview of computational chemistry techniques including molecular mechanics, molecular dynamics, electronic structure theory and continuum medium approaches. Sufficient theoretical background is provided for students to understand the uses and limitations of each technique. An integral part of the course is hands on experience with state-of-the-art computational chemistry tools running on graphics workstations. This is the graduate equivalent of 09-563. Students enrolled in the graduate level course will complete an additional independent project. 3 hrs. lec.

09-768 Machine Learning for Molecular Sciences

Spring: 12 units
The emergence of contemporary artificial intelligence (AI) and machine learning (ML) methods has the potential to substantially alter and enhance the role of computers in science. At the heart of ML applications, lie statistical algorithms whose performance, much like that of a scholar, improves with training. There is a growing infrastructure of machine learning tools for generating, testing and refining scientific models. Such techniques are suitable for addressing complex problems that involve vast combinatorial spaces or complex processes, which conventional procedures either cannot solve or can tackle only at great computational cost. The purpose of this course is to provide a practical introduction to the core concepts and tools of machine learning in a manner easily understood and intuitive to STEM students. The course begins by covering fundamental concepts in ML, data science, and modern statistics such as the bias-variance tradeoff, overfitting, regularization, and generalization, before moving on to more advanced topics in both supervised and unsupervised learning. Topics covered in the course also include ensemble models, neural networks, modern deep learning, embedding, clustering and data visualization. Throughout the course, we emphasize application of ML methods to chemical, physical and biological data. A notable aspect of the course is the hands-on use of Python Jupyter notebooks to introduce modern ML/statistical packages.
Prerequisites: (09-344 or 09-231) and (15-112 or 15-110)

09-803 Chemistry of Gene Expression

Intermittent: 12 units
This course examines the chemical basis of biological reactions required for the propagation of genetic information stored in DNA and the organic chemistry principles behind the structure and function of nucleic acids.Main topics of lectures and class discussion will include the chemical and biochemical syntheses, properties and analyses of natural and modified nucleic acids to investigate cellular processes such as transcription, RNA splicing, other RNA regulation and translation; an introduction to the enzymatic strategies that accelerate these chemical reactions and a comparison of protein enzymes, ribozymes and other nucleic acid based enzymes in contemporary chemistry and biology. Students will learn to critically evaluate current scientific efforts that examine various aspects of chemistry and biological chemistry, the relationship between the structure and function of biomolecular systems, propose experiments to examine biological chemistry research problems and communicate these ideas and participate in scientific discussions and debates. 3 hrs. lec.
Prerequisites: (09-218 or 09-220) and (03-231 or 03-232)

Department of Mathematical Sciences

Prasad Tetali, Department Head

Jason Howell, Associate Head

David Offner, Director of Undergraduate Studies

Location: Wean Hall 6113
www.math.cmu.edu (http://www.math.cmu.edu)

Mathematics provides much of the language and quantitative underpinnings of the natural and social sciences, and mathematical scientists have been responsible for the development of many of the most commonly used tools in business management as well as for laying the foundation for computational and computer science. The name of the Department of Mathematical Sciences reflects its tradition of outstanding research and teaching of applicable mathematics relating to these areas. Indeed, the Department contains highly ranked research groups in Applied Mathematics, Discrete Mathematics, Logic, and Mathematical Finance. These research strengths are reflected in the variety of options that the Department provides for its undergraduate majors.

The Department offers a B.S. degree in Mathematical Sciences. Concentrations within the degree include Mathematical Sciences, Operations Research and Statistics, Statistics, Discrete Mathematics and Logic, and Computational and Applied Mathematics.

The Mathematical Sciences concentration is the least structured of our programs, in recognition of the wide variety of interests that can be productively coupled with the study of mathematical sciences. It can be an appropriate choice for students planning for graduate study in mathematics or seeking to design their curriculum to take advantage of the many opportunities for a second major from another department in the University.

The Operations Research and Statistics concentration prepares students to enter the area of operations research. Mathematicians with a background in operations research are especially valuable in such diverse activities as project planning, production scheduling, market forecasting and finance. Such applications are found in virtually all industrial and governmental settings.

The Statistics concentration prepares students to contribute to a wide variety of research areas. Applications range from experimental design and data analysis in the physical and social sciences, medicine and engineering, to modeling and forecasting in business and government, to actuarial applications in the financial and insurance industries. This is also a useful second major for students planning for graduate study and research in subject areas requiring a strong statistical background.

The Discrete Mathematics and Logic concentration provides a background in discrete mathematics, mathematical logic, and theoretical computer science. This concentration prepares the student to do research in these and related fields, or to apply their ideas elsewhere.

Finally, the Computational and Applied Mathematics concentration provides the background needed to support the computational and mathematical analysis needs of a wide variety of businesses and industries and is well suited to students with an interest in the physical sciences and engineering.

The Department places great emphasis on the advising of students. This is critical if students are to make the most of their years at the University. Students are urged to work carefully with their advisor and other faculty to formulate their degree programs. Study abroad is encouraged, and an interested student should investigate the opportunities available in the Undergraduate Options (p. 20) section of the catalog.

Special Options

The Department offers special opportunities for the exceptionally well-prepared and intellectually ambitious student. These options are available to students from any department in the University.

Matrix Theory and Vector Analysis

For selected freshmen entering the University, the department offers the fall/spring sequence of 21-242 Matrix Theory and 21-269 Vector Analysis, which include a rigorous introduction to proofs and abstract mathematics. Typically, a student choosing this sequence has mastered the operational aspects of high school mathematics and now seeks a deeper conceptual understanding.

- 21-242 Matrix Theory is an honors version of 21-241 Matrices and Linear Transformations .
- 21-269 Vector Analysis is an honors version of 21-268 Multidimensional Calculus .

Admission to 21-242 Matrix Theory is based on an assessment exam taken at the start of the freshman year. Admission to 21-269 Vector Analysis is based on a student's performance in 21-242 Matrix Theory, and on other courses taken in the fall semester.

Mathematical Studies

The sequence of undergraduate honors courses continues with the Mathematical Studies courses, aimed primarily at sophomores. These highly demanding courses provide excellent preparation for graduate study, with many of the participants taking graduate courses as early as their junior year. Students will be expected to master material at a high level of abstraction, and to work on very challenging problems. The typical enrollment of about 15 students allows for close contact with the instructors.

- 21-235 Mathematical Studies Analysis I is an honors version of 21-355 Principles of Real Analysis I.
- 21-237 Mathematical Studies Algebra I is an honors version of 21-373 Algebraic Structures.
- 21-236 Mathematical Studies Analysis II is an honors version of 21-356 Principles of Real Analysis II.
- 21-238 Mathematical Studies Algebra II) is an honors version of 21-341 Linear Algebra.

Admission to Mathematical Studies is by invitation. Interested students should apply during the spring of their freshman year. Applicants are not absolutely required to have taken 21-242 Matrix Theory or 21-269 Vector Analysis, and may be admitted on the basis of exceptionally strong performance in non-honors mathematics courses.

It is possible to take only the algebra courses or only the analysis courses. Admission to 21-236 Mathematical Studies Analysis II requires a grade of B or better in 21-235 Mathematical Studies Analysis I, and similarly, admission to 21-238 Mathematical Studies Algebra II requires a grade of B or better in 21-237 Mathematical Studies Algebra I.

Interdisciplinary Programs

Several interdisciplinary options enable a student to combine mathematics with other disciplines.

- The Bachelor of Science and Arts (p.) program allows a student to combine mathematics with study in any of the five schools in the College of Fine Arts.
- The Bachelor of Science in Mathematics and Economics (p.) is a flexible program which allows students to develop depth in both fields of study. Note: for students whose home college is Dietrich College, this major is known as the Bachelor of Science in Economics and Mathematical Sciences.
- Finally, a joint program with the Heinz College of Public Policy and Management and the Tepper School of Business leads to the degree Bachelor of Science in Computational Finance (p.).

Curriculum

For each concentration, we provide a list of the requirements and a suggested schedule that takes prerequisites into account. A Mathematical Sciences, Computer Science, Physics, Statistics Elective refers to any course from the Departments of Mathematical Sciences, Computer Science, Physics, or Statistics and Data Science, respectively, satisfying the following restrictions: a mathematical sciences course must be at the 21-300 level or above or 21-270 or 21-292, a computer science course must be at the 15-200 level or above, a physics course must be at the 33-300 level or above, and a statistics course must be at the 36-300 level or above and have at least 36-225 as a prerequisite.

Exceptions to the elective requirements for each concentration of the B.S. degree in Mathematical Sciences require prior approval from the student's advisor.

A student preparing for graduate study should also consider undertaking independent work. The Department offers 21-410 Research Topics in Mathematical Sciences and 21-599 Undergraduate Reading and Research for this purpose. At most a total of nine units of 21-410/21-599 can be applied toward the Depth Elective requirement. This requires permission of both the advisor and the department.

Mathematical Sciences majors are required to complete an introductory computer science course, either 15-110 or 15-112. Students who plan to take further computer science courses must complete 15-112.

A Nontechnical Elective refers to a course in the Dietrich College, the College of Fine Arts or the Tepper School of Business. Noted exceptions are described on the Mellon College of Science website (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/). A course listed as an elective is a free elective with the only restriction that the maximum total of ROTC, StuCo, and Physical Education units that will be accepted for graduation is nine.

For a list of courses required for all MCS students, see the MCS General Education Requirements (p.).

B.S. in Mathematical Sciences

This program is the most flexible available to our majors. The flexibility to choose eight electives within the major plus seven humanities courses and seven free electives allows the student to design a program to suit his or her individual needs and interests. By default, students must fulfill all the requirements of the catalog of the year they entered CMU. Students who wish to be considered for a subsequent catalog may submit a request to the Director of Undergraduate Studies. The requirements are:

Mathematical Sciences Courses (required)

The alternative courses 21-242, 21-261, and 21-268 (or 21-269) are particularly recommended for a student planning to pursue graduate work.

Courses		Units
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	12
or 21-128	Mathematical Concepts and Proofs	
21-201	Undergraduate Colloquium	1
21-228	Discrete Mathematics	9-12
or 15-251	Great Ideas in Theoretical Computer Science	
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
21-259	Calculus in Three Dimensions	10-12
or 21-266	Vector Calculus for Computer Scientists	
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
21-260	Differential Equations	9-10
or 21-261	Introduction to Ordinary Differential Equations	
or 33-231	Physical Analysis	
21-325	Probability	9-12
or 15-259	Probability and Computing	
or 36-218	Probability Theory for Computer Scientists	
21-341	Linear Algebra	9
21-355	Principles of Real Analysis I	9-12
or 21-455	Intermediate Real Analysis I	
21-356	Principles of Real Analysis II	9-10
or 21-456	Intermediate Real Analysis II	
21-373	Algebraic Structures	9
		117-130

Forty-five units of (required) Mathematical Sciences electives (at the 21-300 level or above or 21-270 or 21-292).

Twenty-seven units of (required) Mathematical Sciences (at the 21-300 level or above or 21-270 or 21-292, or Computer Science (at the 15-200 level or above), or Physics (at the 33-300 level or above), or Statistics (must be at the 36-300 level or above and have at least 36-225 as a prerequisite) electives.

MCS General Education (required)

MCS humanities, social sciences, and science core (114 units)

Mathematical Sciences Electives for Students Intending Graduate Studies

Students preparing for graduate study in mathematics should consider the following courses as Mathematical Sciences electives, choosing among them according to the desired area of graduate study. Exceptions to the elective requirements for each concentration of the B.S. degree in Mathematical Sciences require prior approval from the student's academic advisor.

Courses		Units
21-301	Combinatorics	9
21-360	Differential Geometry of Curves and Surfaces	9
21-371	Functions of a Complex Variable	9
21-374	Field Theory	9
21-441	Number Theory	9
21-465	Topology	9
21-470	Selected Topics in Analysis	9
21-476	Introduction to Dynamical Systems	9
21-484	Graph Theory	9
21-602	Introduction to Set Theory I	12
21-603	Model Theory I	12
21-610	Algebra I	12
21-620	Real Analysis	6
21-621	Introduction to Lebesgue Integration	6
21-630	Ordinary Differential Equations	12
21-632	Introduction to Differential Equations	12
21-640	Introduction to Functional Analysis	12
21-651	General Topology	12
21-660	Introduction to Numerical Analysis I	12
21-701	Discrete Mathematics	12
21-720	Measure and Integration	12
21-721	Probability	12
21-723	Advanced Real Analysis	12
21-737	Probabilistic Combinatorics	12
21-738	Extremal Combinatorics	12

Note that courses 21-600 and above carry graduate credit. Courses at the 600 level are designed as transitional courses to graduate study. A student preparing for graduate study should also consider undertaking independent work. The Department offers 21-410 Research Topics in Mathematical Sciences and 21-599 Undergraduate Reading and Research for this purpose.

Courses 21-700 and above can be used with the permission of both the advisor and the department.

Suggested Schedule for students without Advanced credit for 21-120 and 21-122

Freshman Year

Fall		Units
21-120	Differential and Integral Calculus	10
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
38-101	EUREKA!: Discovery and Its Impact	6
76-101	Interpretation and Argument	9
99-101	Core@CMU	3
xx-xxx	Technical Breadth Requirement	9
		48

Spring		Units
15-110	Principles of Computing	10-12
or 15-112	Fundamentals of Programming and Computer Science	
21-127	Concepts of Mathematics	12
or 21-128	Mathematical Concepts and Proofs	
21-122	Integration and Approximation	10
xx-xxx	Technical Breadth Requirement	9
xx-xxx	Nontechnical Elective	9
		50-52

Sophomore Year

Fall		Units
21-201	Undergraduate Colloquium	1
21-228	Discrete Mathematics	9-12
or 15-251	Great Ideas in Theoretical Computer Science	
21-268	Multidimensional Calculus	11
xx-xxx	Technical Breadth Requirement	9
xx-xxx	Nontechnical Elective	9
xx-xxx	Free Elective	9
		48-51

Spring		Units
21-261	Introduction to Ordinary Differential Equations	10
21-373	Algebraic Structures	9
38-230	ENGAGE in Wellness: Looking Inward	1
xx-xxx	Technical Breadth Requirement	9
xx-xxx	Technical Breadth Requirement	9
xx-xxx	Nontechnical Elective	9
		47

Junior Year

Fall		Units
21-355	Principles of Real Analysis I	9-12
or 21-455	Intermediate Real Analysis I	
21-325	Probability	9-12
or 15-259	Probability and Computing	
or 36-218	Probability Theory for Computer Scientists	
38-330	ENGAGE in Wellness: Looking Outward	1
xx-xxx	Technical Breadth Requirement	9
xx-xxx	Nontechnical Elective	9
xx-xxx	Free Elective	9
		46-52

Spring		Units
21-341	Linear Algebra	9
21-356	Principles of Real Analysis II	9-10
or 21-456	Intermediate Real Analysis II	
21-xxx	Mathematical Sciences Elective	9
xx-xxx	Science and Society Course	6
xx-xxx	Cultural/Global Understanding Elective	9
		42-43

Senior Year

Fall		Units
21-xxx	Mathematical Sciences Elective	9
21-xxx	Mathematical Sciences Elective	9
38-110	ENGAGE in Service [1]	1
38-220	ENGAGE in the Arts [1]	2
38-430	ENGAGE in Wellness: Looking Forward	1
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
		40

Spring		Units
21-xxx	Mathematical Sciences Elective	9
21-xxx	Mathematical Sciences Elective	9
xx-xxx	Technical Breadth Requirement	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
		45

Minimum number of units required for degree:	360

Suggested Schedule for Students with Advanced Credit for 21-120 and 21-122

Freshman Year

Fall		Units
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
21-127	Concepts of Mathematics	12
or 21-128	Mathematical Concepts and Proofs	
38-101	EUREKA!: Discovery and Its Impact	6
76-101	Interpretation and Argument	9
99-101	Core@CMU	3
xx-xxx	Technical Breadth Requirements	9
		50

Spring		Units
15-110	Principles of Computing	10-12
or 15-112	Fundamentals of Programming and Computer Science	
21-228	Discrete Mathematics	9-12
or 15-251	Great Ideas in Theoretical Computer Science	
21-268	Multidimensional Calculus	11-12
or 21-269	Vector Analysis	
xx-xxx	Nontechnical Elective	9
		39-45

Sophomore Year

Fall		Units
21-325	Probability	9-12
or 15-259	Probability and Computing	
or 36-218	Probability Theory for Computer Scientists	
21-373	Algebraic Structures	9
xx-xxx	Technical Breadth Requirement	9
xx-xxx	Nontechnical Elective	9
xx-xxx	Free Elective	9
		45-48

Spring		Units
21-261	Introduction to Ordinary Differential Equations	10
21-355	Principles of Real Analysis I	9-12
or 21-455	Intermediate Real Analysis I	
38-230	ENGAGE in Wellness: Looking Inward	1
xx-xxx	Technical Breadth Requirement	9
xx-xxx	Nontechnical Elective	9
		38-41

Junior Year

Fall		Units
21-356	Principles of Real Analysis II	9-10
or 21-456	Intermediate Real Analysis II	
21-xxx	Mathematical Sciences Elective	9
38-330	ENGAGE in Wellness: Looking Outward	1
xx-xxx	Cultural/Global Understanding Course	9
xx-xxx	Free Elective	9
		37-38

Spring		Units
21-341	Linear Algebra	9
21-xxx	Mathematical Sciences Elective	9
xx-xxx	Science and Society Course	6
xx-xxx	Technical Breadth Requirement	9
xx-xxx	Nontechnical Elective	9
		42

Senior Year

Fall		Units
21-xxx	Mathematical Sciences Elective	9

21-xxx	Mathematical Sciences Elective	9
38-110	ENGAGE in Service [1]	1
38-220	ENGAGE in the Arts [1]	2
38-430	ENGAGE in Wellness: Looking Forward	1
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
		49

Spring		Units
21-xxx	Mathematical Sciences Elective	9
21-xxx	Mathematical Sciences Elective	9
xx-xxx	Technical Breadth Requirement	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
		45

Minimum number of units required for degree: 360

B.S. in Mathematical Sciences (Operations Research and Statistics)

An operations research professional employs quantitative and computational skills toward enhancing the function of an organization or process. Students choosing this concentration will develop problem-solving abilities in mathematical and statistical modeling and computer-based simulation in areas such as network design, transportation scheduling, allocation of resources and optimization. In addition to courses in mathematics and statistics, a basic background in economics and accounting is included. Since problems in business and industry are often solved by teams, the curriculum typically includes group projects. Students choosing this concentration may not pursue an additional minor in Statistics in the Dietrich College of Humanities and Social Sciences College. By default, students must fulfill all the requirements of the catalog of the year they entered CMU. Students who wish to be considered for a subsequent catalog may submit a request to the Director of Undergraduate Studies.

The requirements for the concentration in Operations Research and Statistics are:

Mathematical Sciences Courses (required)

The alternative courses 21-242, 21-261, and 21-268 (or 21-269) are particularly recommended for a student planning to pursue graduate work.

Courses		Units
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	12
or 21-128	Mathematical Concepts and Proofs	
21-201	Undergraduate Colloquium	1
21-228	Discrete Mathematics	9-12
or 15-251	Great Ideas in Theoretical Computer Science	
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
21-259	Calculus in Three Dimensions	10-12
or 21-266	Vector Calculus for Computer Scientists	
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
21-260	Differential Equations	9-10
or 21-261	Introduction to Ordinary Differential Equations	
or 33-231	Physical Analysis	
21-292	Operations Research I	9
21-369	Numerical Methods	12
21-393	Operations Research II	9
		102-108

Statistics Courses (required)

Courses		Units
21-325	Probability	9-12
or 15-259	Probability and Computing	
or 36-218	Probability Theory for Computer Scientists	
36-226	Introduction to Statistical Inference	9
36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9
36-410	Introduction to Probability Modeling	9
		45-48

Economics, Business, and Computer Science Courses (required)

Courses		Units
15-110	Principles of Computing	10
70-122	Introduction to Accounting	9
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
or 73-240	Intermediate Macroeconomics	
		46

Depth Electives (required)

Forty-five units of (required) depth electives, to be chosen from the list below. At least one should be a math course (21-xxx). The courses 21-355 and 21-455 are particularly recommended for a student planning to pursue graduate work. Exceptions to the elective requirements for each concentration of the B.S. degree in Mathematical Sciences require prior approval from the student's academic advisor.

Courses		Units
10-301	Introduction to Machine Learning	12
or 10-315	Introduction to Machine Learning (SCS Majors)	
10-605	Machine Learning with Large Datasets	12
15-122	Principles of Imperative Computation	12
15-150	Principles of Functional Programming	12
15-210	Parallel and Sequential Data Structures and Algorithms	12
21-270	Introduction to Mathematical Finance	9
21-301	Combinatorics	9
21-321	Interactive Theorem Proving	9
21-341	Linear Algebra	9
21-355	Principles of Real Analysis I	9-12
or 21-455	Intermediate Real Analysis I	
21-356	Principles of Real Analysis II	9-10
or 21-456	Intermediate Real Analysis II	
21-366	Topics in Applied Mathematics	9
21-370	Discrete Time Finance	9
21-373	Algebraic Structures	9
21-377	Monte Carlo Simulation for Finance	9
21-378	Mathematics of Fixed Income Markets	9
21-387	Monte Carlo Methods and Applications	9
21-420	Continuous-Time Finance	9
21-484	Graph Theory	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Statistical Machine Learning	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Psychometrics: A Statistical Modeling Approach	9
70-371	Operations Management	9
70-460	Mathematical Models for Consulting	9
70-467	Machine Learning for Business Analytics	9
70-469	End to End Business Analytics	9
70-471	Supply Chain Management	9

MCS General Education (required)

MCS humanities, social sciences, and science core (114 units)

Note that 73-102, 73-103, 73-230, and 73-240 satisfy requirements from the MCS general education core.

Suggested Schedule

Freshman Year

Fall		Units
21-120	Differential and Integral Calculus	10
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
38-101	EUREKA!: Discovery and Its Impact	6
76-101	Interpretation and Argument	9
99-101	Core@CMU	3
xx-xxx	Technical Breadth Requirement	9
		48

Spring		Units
15-110	Principles of Computing	10-12
or 15-112	Fundamentals of Programming and Computer Science	
21-127	Concepts of Mathematics	12
or 21-128	Mathematical Concepts and Proofs	
21-122	Integration and Approximation	10
xx-xxx	Technical Breadth Requirement	9
xx-xxx	Nontechnical Elective	9
		50-52

Sophomore Year

Fall		Units
21-201	Undergraduate Colloquium	1
21-228	Discrete Mathematics	9-12
or 15-251	Great Ideas in Theoretical Computer Science	
21-259	Calculus in Three Dimensions	10-12
or 21-266	Vector Calculus for Computer Scientists	
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
73-102	Principles of Microeconomics	9
xx-xxx	Technical Breadth Requirement	9
		38-43

Spring		Units
21-260	Differential Equations	9-10
or 21-261	Introduction to Ordinary Differential Equations	
or 33-231	Physical Analysis	
21-292	Operations Research I	9
38-230	ENGAGE in Wellness: Looking Inward	1
70-122	Introduction to Accounting	9
xx-xxx	Technical Breadth Requirement	9
xx-xxx	Nontechnical Elective	9
		46-47

Junior Year

Fall		Units
21-369	Numerical Methods	12
21-325	Probability	9-12
or 15-259	Probability and Computing	
or 36-218	Probability Theory for Computer Scientists	
73-103	Principles of Macroeconomics	9
xx-xxx	Depth Elective	9
38-330	ENGAGE in Wellness: Looking Outward	1
		40-43

Spring		Units
36-226	Introduction to Statistical Inference	9
36-410	Introduction to Probability Modeling	9
73-230	Intermediate Microeconomics	9
or 73-240	Intermediate Macroeconomics	
xx-xxx	Depth Elective	9
xx-xxx	Science and Society Course	6
xx-xxx	Cultural/Global Understanding Course	9
		51

Senior Year

Fall		Units
21-393	Operations Research II	9
36-401	Modern Regression	9
xx-xxx	Depth Elective	9
38-110	ENGAGE in Service [1]	1
38-220	ENGAGE in the Arts [1]	2
38-430	ENGAGE in Wellness: Looking Forward	1
xx-xxx	Nontechnical Elective	9
xx-xxx	Free Elective	9
		49

Spring		Units
36-402	Advanced Methods for Data Analysis	9
xx-xxx	Depth Elective	9
xx-xxx	Depth Elective	9
xx-xxx	Nontechnical Elective	9
xx-xxx	Free Elective	9
		45

Minimum number of units required for degree:	360

B.S. in Mathematical Sciences (Statistics)

Statistics is concerned with the process by which inferences are made from data. Statistical methods are essential to research in a wide variety of scientific disciplines. For example, principles of experimental design that assist chemists in improving their yields also help poultry farmers grow bigger chickens. Similarly, time series analysis is used to better understand radio waves from distant galaxies, hormone levels in the blood, and concentrations of pollutants in the atmosphere. This diversity of application is an exciting aspect of the field, and it is one reason for the current demand for well-trained statisticians.

The courses 15-259 Probability and Computing and 36-226 Introduction to Statistical Inference taken in the junior year serve as the basis for all further statistics courses. The course 21-325 is a more mathematical alternative to 15-259.

The Statistics concentration is jointly administered by the Department of Mathematical Sciences and the Department of Statistics and Data Science. Students choosing this concentration may not pursue an additional minor in Statistics in the Dietrich College of Humanities and Social Sciences. By default, students must fulfill all the requirements of the catalog of the year they entered CMU. Students who wish to be considered for a subsequent catalog may submit a request to the Director of Undergraduate Studies. The requirements for the Statistics concentration are:

Mathematical Sciences Courses (required)

The alternative courses 21-242, 21-261, and 21-268 (or 21-269) are particularly recommended for a student planning to pursue graduate work.

Courses		Units
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	12
or 21-128	Mathematical Concepts and Proofs	
21-201	Undergraduate Colloquium	1
21-228	Discrete Mathematics	9-12
or 15-251	Great Ideas in Theoretical Computer Science	
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
21-259	Calculus in Three Dimensions	10-12
or 21-266	Vector Calculus for Computer Scientists	
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
21-260	Differential Equations	9-10
or 21-261	Introduction to Ordinary Differential Equations	
or 33-231	Physical Analysis	
21-292	Operations Research I	9
21-369	Numerical Methods	12
21-393	Operations Research II	9
		102-108

Statistics Courses (required)

Courses		Units
21-325	Probability	9-12
or 15-259	Probability and Computing	
or 36-218	Probability Theory for Computer Scientists	
36-226	Introduction to Statistical Inference	9
36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9
36-410	Introduction to Probability Modeling	9
		45-48

Economics and Computer Science Courses (required)

Courses		Units
15-112	Fundamentals of Programming and Computer Science	12
15-122	Principles of Imperative Computation	12
73-102	Principles of Microeconomics	9
		33

Depth Electives (required)

Forty-five units of (required) depth electives, including at least nine units in statistics, to be chosen from the list below. The courses 21-355 and 21-455 are particularly recommended for a student planning to pursue graduate work. Exceptions to the elective requirements for each concentration of the B.S. degree in Mathematical Sciences require prior approval from the student's academic advisor.

Courses		Units
10-301	Introduction to Machine Learning	12
or 10-315	Introduction to Machine Learning (SCS Majors)	
10-605	Machine Learning with Large Datasets	12
15-150	Principles of Functional Programming	12
15-210	Parallel and Sequential Data Structures and Algorithms	12
21-270	Introduction to Mathematical Finance	9
21-321	Interactive Theorem Proving	9
21-341	Linear Algebra	9
21-355	Principles of Real Analysis I	9-12
or 21-455	Intermediate Real Analysis I	
21-356	Principles of Real Analysis II	9-10
or 21-456	Intermediate Real Analysis II	
21-366	Topics in Applied Mathematics	9
21-370	Discrete Time Finance	9
21-373	Algebraic Structures	9
21-377	Monte Carlo Simulation for Finance	9
21-378	Mathematics of Fixed Income Markets	9
21-387	Monte Carlo Methods and Applications	9
21-420	Continuous-Time Finance	9
21-484	Graph Theory	9
36-461	Special Topics: Statistical Methods in Epidemiology	9
36-462	Special Topics: Statistical Machine Learning	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Psychometrics: A Statistical Modeling Approach	9

MCS General Education (required)

MCS humanities, social sciences, and science core (114 units)

Note that 73-102 satisfies a requirement from the MCS core.

Suggested Schedule

Freshman Year

Fall		Units
21-120	Differential and Integral Calculus	10
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
38-101	EUREKA!: Discovery and Its Impact	6
76-101	Interpretation and Argument	9
99-101	Core@CMU	3
xx-xxx	Technical Breadth Requirement	9
		48

Spring		Units
15-112	Fundamentals of Programming and Computer Science	12
21-127	Concepts of Mathematics	12
or 21-128	Mathematical Concepts and Proofs	
21-122	Integration and Approximation	10
xx-xxx	Technical Breadth Requirement	9
xx-xxx	Technical Breadth Requirement	9
		52

Sophomore Year

Fall		Units
21-201	Undergraduate Colloquium	1
21-228	Discrete Mathematics	9-12
or 15-251	Great Ideas in Theoretical Computer Science	
21-259	Calculus in Three Dimensions	10-12
or 21-266	Vector Calculus for Computer Scientists	
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
73-102	Principles of Microeconomics	9
xx-xxx	Technical Breadth Requirements	9
xx-xxx	Nontechnical Elective	9
		47-52

Spring		Units
15-122	Principles of Imperative Computation	12
21-260	Differential Equations	9-10
or 21-261	Introduction to Ordinary Differential Equations	
or 33-231	Physical Analysis	
21-292	Operations Research I	9
38-230	ENGAGE in Wellness: Looking Inward	1
xx-xxx	Nontechnical Elective	9
xx-xxx	Free Elective	9
		49-50

Junior Year

Fall		Units
21-369	Numerical Methods	12
21-325	Probability	9-12
or 15-259	Probability and Computing	
or 36-218	Probability Theory for Computer Scientists	
xx-xxx	Depth Elective	9
xx-xxx	Depth Elective	9
38-330	ENGAGE in Wellness: Looking Outward	1
xx-xxx	Nontechnical Elective	9
		49-52

Spring		Units
36-226	Introduction to Statistical Inference	9
36-410	Introduction to Probability Modeling	9
xx-xxx	Depth Elective	9
xx-xxx	Science and Society Course	6
xx-xxx	Cultural/Global Understanding Course	9
		42

Senior Year

Fall		Units
21-393	Operations Research II	9
36-401	Modern Regression	9
xx-xxx	Depth Elective	9
38-110	ENGAGE in Service [1]	1
38-220	ENGAGE in the Arts [1]	2

38-430	ENGAGE in Wellness: Looking Forward	1
xx-xxx	Nontechical Elective	9
		40

Spring		Units
36-402	Advanced Methods for Data Analysis	9
xx-xxx	Depth Elective	9
xx-xxx	Depth Elective	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
		45

Minimum number of units required for degree: 360

B.S. in Mathematical Sciences (Discrete Mathematics and Logic)

Discrete mathematics is the study of finite and countable structures and algorithms for the manipulation and analysis of such structures, while mathematical logic is the study of axiomatic systems and their mathematical applications. Both are flourishing research areas and have close ties with computer science.

The Discrete Mathematics and Logic concentration provides a firm background in discrete mathematics and mathematical logic, together with the elements of theoretical computer science. It prepares the student to pursue research in these fields, or to apply their ideas in the many disciplines (ranging from philosophy to hardware verification) where such ideas have proved relevant. By default, students must fulfill all the requirements of the catalog of the year they entered CMU. Students who wish to be considered for a subsequent catalog may submit a request to the Director of Undergraduate Studies.

The requirements for the Discrete Mathematics and Logic concentration are:

Mathematical Sciences and Computer Science Courses (required)

The alternative course 21-242 is particularly recommended for a student planning to pursue graduate work. Students who plan to pursue graduate study in mathematical logic are strongly advised to take 21-300 Basic Logic.

Courses		Units
15-122	Principles of Imperative Computation	12
15-150	Principles of Functional Programming	12
15-210	Parallel and Sequential Data Structures and Algorithms	12
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	12
or 21-128	Mathematical Concepts and Proofs	
21-201	Undergraduate Colloquium	1
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
21-300	Basic Logic	9
or 15-317	Constructive Logic	
21-228	Discrete Mathematics	9-12
or 15-251	Great Ideas in Theoretical Computer Science	
21-301	Combinatorics	9
21-341	Linear Algebra	9
21-355	Principles of Real Analysis I	9-12
or 21-455	Intermediate Real Analysis I	
21-373	Algebraic Structures	9
		134-140

Computer Science Electives (required)

Any two courses at the 300 level or above. The following are specifically suggested:

15-312	Foundations of Programming Languages	12
15-451	Algorithm Design and Analysis	12
15-453	Formal Languages, Automata, and Computability	9

Students pursuing this concentration who minor in Computer Science must take at least 18 units of 15-300 level (or above) courses to avoid excessive double-counting.

Mathematical Sciences Electives (required)

Sixty-three units of mathematical sciences electives, to be chosen from List 1 and 2 below, including at least twenty-seven units chosen from List 1. Exceptions to the elective requirements for each concentration of the B.S. degree in Mathematical Sciences require prior approval from the student's academic advisor.

List 1 (Discrete Mathematics and Logic Electives)

Courses		Units
15-259	Probability and Computing	12
21-321	Interactive Theorem Proving	9
21-322	Topics in Formal Mathematics	9
21-325	Probability	9
21-329	Set Theory	9
21-374	Field Theory	9
21-400	Intermediate Logic	9
21-441	Number Theory	9
21-484	Graph Theory	9
21-602	Introduction to Set Theory I	12
21-603	Model Theory I	12
21-610	Algebra I	12
21-701	Discrete Mathematics	12
80-305	Game Theory	9
80-411	Proof Theory	9
80-413	Category Theory	9

List 2 (General Mathematics Electives)

Courses		Units
21-259	Calculus in Three Dimensions	10-12
or 21-266	Vector Calculus for Computer Scientists	
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
21-260	Differential Equations	9-10
or 21-261	Introduction to Ordinary Differential Equations	
or 33-231	Physical Analysis	
21-270	Introduction to Mathematical Finance	9
21-292	Operations Research I	9
21-356	Principles of Real Analysis II	9-10
or 21-456	Intermediate Real Analysis II	
21-366	Topics in Applied Mathematics	9
21-369	Numerical Methods	12
21-370	Discrete Time Finance	9
21-371	Functions of a Complex Variable	9
21-387	Monte Carlo Methods and Applications	9
21-393	Operations Research II	9
21-420	Continuous-Time Finance	9
21-470	Selected Topics in Analysis	9
21-476	Introduction to Dynamical Systems	9
21-410	Research Topics in Mathematical Sciences	9
21-xxx	Any graduate course in mathematics at the 600 and 700 level not included in List 1	9-12

MCS General Education (required)

MCS humanities, social sciences, and science core (114 units)

Suggested Schedule

Freshman Year

Fall		Units
15-112	Fundamentals of Programming and Computer Science	12
21-120	Differential and Integral Calculus	10
38-101	EUREKA!: Discovery and Its Impact	6
76-101	Interpretation and Argument	9
99-101	Core@CMU	3

xx-xxx	Life/Physical Sciences Course	9
		49

Spring		Units
15-122	Principles of Imperative Computation	12
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	12
or 21-128	Mathematical Concepts and Proofs	
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
xx-xxx	Technical Breadth Requirement	9
		54

Sophomore Year

Fall		Units
15-150	Principles of Functional Programming	12
21-201	Undergraduate Colloquium	1
21-268	Multidimensional Calculus	11-12
or 21-269	Vector Analysis	
21-301	Combinatorics	9
21-373	Algebraic Structures	9
xx-xxx	Nontechnical Elective	9
		51-52

Spring		Units
15-210	Parallel and Sequential Data Structures and Algorithms	12
38-230	ENGAGE in Wellness: Looking Inward	1
xx-xxx	Discrete Math/Logic Elective	9
xx-xxx	Mathematics Elective	9
xx-xxx	Technical Breadth Requirement	9
xx-xxx	Nontechnical Elective	9
		49

Junior Year

Fall		Units
15-xxx	Computer Science Elective	9
21-300	Basic Logic	9
or 15-317	Constructive Logic	
21-355	Principles of Real Analysis I	9-12
or 21-455	Intermediate Real Analysis I	
38-330	ENGAGE in Wellness: Looking Outward	1
xx-xxx	Technical Breadth Requirement	9
xx-xxx	Nontechnical Elective	9
		46-49

Spring		Units
15-xxx	Computer Science Elective	9
21-341	Linear Algebra	9
xx-xxx	Science and Society Course	6
xx-xxx	Nontechnical Elective	9
xx-xxx	Cultural/Global Understanding Course	9
		42

Senior Year

Fall		Units
xx-xxx	Discrete Math/Logic Elective	9
xx-xxx	Mathematics Elective	9
xx-xxx	Mathematics Elective	9
38-110	ENGAGE in Service [1]	1
38-220	ENGAGE in the Arts [1]	2
38-430	ENGAGE in Wellness: Looking Forward	1
xx-xxx	Free Elective	9
		40

Spring		Units
xx-xxx	Discrete Math/Logic Elective	9
xx-xxx	Mathematics Elective	9
xx-xxx	Mathematics Elective	9
xx-xxx	Free Elective	9
		36

Minimum number of units required for degree: 360

B.S. in Mathematical Sciences (Computational and Applied Mathematics)

This concentration is designed to prepare students for careers in business or industry which require significant analytical, computational and problem solving skills. It also prepares students with interest in computational and applied mathematics for graduate school.

The students in this concentration develop skills to choose the right framework to quantify or model a problem, analyze it, simulate and in general use appropriate techniques for carrying the effort through to an effective solution. The free electives allow the student to develop an interest in a related area by completing a minor in another department, such as Engineering Studies, Economics, Information Systems or Business Administration. By default, students must fulfill all the requirements of the catalog of the year they entered CMU. Students who wish to be considered for a subsequent catalog may submit a request to the Director of Undergraduate Studies.

The requirements for the Computational and Applied Mathematics concentration are:

Mathematical Sciences Courses (required)

The alternative courses 21-242, 21-261, and 21-268 (or 21-269) are particularly recommended for a student planning to pursue graduate work.

Courses		Units
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	12
or 21-128	Mathematical Concepts and Proofs	
21-201	Undergraduate Colloquium	1
21-228	Discrete Mathematics	9-12
or 15-251	Great Ideas in Theoretical Computer Science	
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
21-259	Calculus in Three Dimensions	10-12
or 21-266	Vector Calculus for Computer Scientists	
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
21-260	Differential Equations	9-10
or 21-261	Introduction to Ordinary Differential Equations	
or 33-231	Physical Analysis	
21-325	Probability	9-12
or 15-259	Probability and Computing	
or 36-218	Probability Theory for Computer Scientists	
21-355	Principles of Real Analysis I	9-12
or 21-455	Intermediate Real Analysis I	
21-369	Numerical Methods	12
21-469	Computational Introduction to Partial Differential Equations	12
		114-126

Depth Electives (required)

Students must take twenty-seven units of depth electives, to be chosen from the list below. Exceptions to the elective requirements for each concentration of the B.S. degree in Mathematical Sciences require prior approval from the student's academic advisor.

Courses		Units
10-301	Introduction to Machine Learning	12
or 10-315	Introduction to Machine Learning (SCS Majors)	
21-270	Introduction to Mathematical Finance	9
21-292	Operations Research I	9
21-344	Numerical Linear Algebra	9
21-380	Introduction to Mathematical Modeling	9
21-435	Applied Harmonic Analysis	9

Computer Science Courses (required)

Courses		Units
15-122	Principles of Imperative Computation	12

Mathematics Electives (required)

Students must take 27 units either from the three remaining courses from the depth electives or from the list below:

Courses		Units
21-321	Interactive Theorem Proving	9
21-322	Topics in Formal Mathematics	9
21-341	Linear Algebra	9
21-356	Principles of Real Analysis II	9-10
or 21-456	Intermediate Real Analysis II	
21-366	Topics in Applied Mathematics	9
21-370	Discrete Time Finance	9
21-371	Functions of a Complex Variable	9
21-373	Algebraic Structures	9
21-377	Monte Carlo Simulation for Finance	9
21-378	Mathematics of Fixed Income Markets	9
21-387	Monte Carlo Methods and Applications	9
21-393	Operations Research II	9
21-420	Continuous-Time Finance	9
21-470	Selected Topics in Analysis	9
21-476	Introduction to Dynamical Systems	9
21-484	Graph Theory	9
21-620	Real Analysis	6
21-621	Introduction to Lebesgue Integration	6
21-630	Ordinary Differential Equations	12
21-632	Introduction to Differential Equations	12
21-640	Introduction to Functional Analysis	12
21-651	General Topology	12
21-660	Introduction to Numerical Analysis I	12
21-690	Methods of Optimization	12
21-720	Measure and Integration	12
21-721	Probability	12
21-723	Advanced Real Analysis	12
21-732	Partial Differential Equations I	12
21-832	Partial Differential Equations II	12

Students must take nine additional units of Mathematical Sciences (at the 21-300 level or above or 21-270 or 21-292), or Computer Science (at the 15-200 level or above), or Physics (at the 33-300 level or above), or Statistics (must be at the 36-300 level or above and have at least 36-225 as a prerequisite) electives.

21-366 Topics in Applied Mathematics and 21-470 Selected Topics in Analysis have content that varies from year to year. These courses can be taken more than once (with permission).

Note that courses 21-600 and above carry graduate credit. 600-level courses are designed as transitional courses to graduate study.

A student preparing for graduate study should also consider undertaking independent work. The Department offers 21-410 Research Topics in Mathematical Sciences and 21-599 Undergraduate Reading and Research for this purpose.

Courses 21-700 and above can be used with the permission of both the advisor and the department.

MCS General Education (required)

MCS humanities, social sciences, and science core (114 units).

Suggested Schedule

Freshman Year

Fall		Units
21-120	Differential and Integral Calculus	10
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
38-101	EUREKA!: Discovery and Its Impact	6
76-101	Interpretation and Argument	9
xx-xxx	Technical Breadth Requirement	9
		45

Spring		Units
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	12
or 21-128	Mathematical Concepts and Proofs	
21-228	Discrete Mathematics	9
xx-xxx	Technical Breadth Requirement	9
xx-xxx	Nontechnical Elective	9
		49

Sophomore Year

Fall		Units
15-112	Fundamentals of Programming and Computer Science	12
21-201	Undergraduate Colloquium	1
21-268	Multidimensional Calculus	11-12
or 21-269	Vector Analysis	
xx-xxx	Technical Breadth Requirement	9
xx-xxx	Nontechnical Elective	9
		42-43

Spring		Units
15-122	Principles of Imperative Computation	12
21-261	Introduction to Ordinary Differential Equations	10
21-355	Principles of Real Analysis I	9-12
or 21-455	Intermediate Real Analysis I	
38-230	ENGAGE in Wellness: Looking Inward	1
xx-xxx	Technical Breadth Requirement	9
xx-xxx	Nontechnical Elective	9
		50-53

Junior Year

Fall		Units
21-325	Probability	9-12
or 15-259	Probability and Computing	
or 36-218	Probability Theory for Computer Scientists	
21-356	Principles of Real Analysis II	9-10
or 21-456	Intermediate Real Analysis II	
38-330	ENGAGE in Wellness: Looking Outward	1
xx-xxx	Nontechnical Elective	9
xx-xxx	Free Elective	9
		37-41

Spring		Units
21-369	Numerical Methods	12
xx-xxx	Mathematics Elective	9
xx-xxx	Depth Elective	9
xx-xxx	Science and Society Course	
xx-xxx	Cultural/Global Understanding Elective	9
xx-xxx	Free Elective	9
		48

Senior Year

Fall		Units
xx-xxx	Mathematics Elective	9
xx-xxx	Mathematics Elective	9
xx-xxx	Depth Elective	9
38-110	ENGAGE in Service [1]	1
38-220	ENGAGE in the Arts [1]	2
38-430	ENGAGE in Wellness: Looking Forward	1
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
		49

Spring		Units
xx-xxx	Mathematics Elective	9

xx-xxx	Depth Elective	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
xx-xxx	Free Elective	9
		45

Minimum number of units required for degree: 360

B.A. in Mathematical Sciences

Mathematical Sciences Courses (required)

21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	12
or 21-128	Mathematical Concepts and Proofs	
21-201	Undergraduate Colloquium	1
21-228	Discrete Mathematics	9-12
or 15-251	Great Ideas in Theoretical Computer Science	
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
21-259	Calculus in Three Dimensions	10-12
or 21-266	Vector Calculus for Computer Scientists	
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
21-260	Differential Equations	9-10
or 21-261	Introduction to Ordinary Differential Equations	
or 33-231	Physical Analysis	
21-325	Probability	9-12
or 15-259	Probability and Computing	
or 36-218	Probability Theory for Computer Scientists	

Forty-five units of Mathematical Sciences electives (at the 21-300 level or above; or 21-270 or 21-292).

Twenty-seven units of Mathematical Sciences (at the 21-300 level or above; or 21-270 or 21-292), or Computer Science (at the 15-200 level or above; or Physics (at the 33-300 level or above; or Statistics (at the 36-300 level or above; and have at least 36-225 as a prerequisite) electives.

MCS General Education (required)

MCS humanities, social sciences, and science core (114 units)

[1] Students must register for this course no later than their penultimate semester. But, work for this course can be begun in any semester prior to registration.

Additional Major Requirements

All concentrations within the B.S. in Mathematical Sciences are available as an additional major to students majoring in other departments. The requirements for the additional majors are the same as those for the B.S degrees, except that the MCS General Education requirements are waived. In order to avoid double-counting issues, students are encouraged to consult with their degree advisor as well as their additional major advisor. Please visit the Department of Mathematical Sciences Undergraduate FAQ website (https://www.cmu.edu/math/undergrad/faq.html) (under "Admissions") for further details

The Minor in Mathematical Sciences

The minor includes six courses. 21-127 Concepts of Mathematics is a prerequisite for 21-228 and recommended for 21-241 . The minimum preparation required for 21-355 Principles of Real Analysis I is 21-122 and 21-127 or equivalent courses. Please see below if you are a Computational Finance major.

21-127	Concepts of Mathematics	12
or 21-128	Mathematical Concepts and Proofs	
or 15-151	Mathematical Foundations for Computer Science	
21-228	Discrete Mathematics	9-12
or 15-251	Great Ideas in Theoretical Computer Science	
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
21-355	Principles of Real Analysis I	9-12
or 21-455	Intermediate Real Analysis I	
21-xxx	Mathematical Sciences Elective (300-level or higher)	9-12
21-xxx	Mathematical Sciences Elective (300-level or higher)	9-12

To avoid excessive double-counting, the two mathematical sciences electives may not also count toward any other major or minor requirement.

Computational Finance majors who declare a minor in Mathematical Sciences should take the following six courses:

Required courses are:

21-127	Concepts of Mathematics	12
or 21-128	Mathematical Concepts and Proofs	
or 15-151	Mathematical Foundations for Computer Science	
21-228	Discrete Mathematics	9-12
or 15-251	Great Ideas in Theoretical Computer Science	
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
21-355	Principles of Real Analysis I	9
21-325	Probability	9-12
or 15-259	Probability and Computing	
or 36-218	Probability Theory for Computer Scientists	

Nine units of Mathematical Sciences Electives, to be chosen from the following list:

21-300	Basic Logic	9
21-301	Combinatorics	9
21-329	Set Theory	9
21-373	Algebraic Structures	9
21-484	Graph Theory	9

**Students who take 21-325 (or 15-259 or 36-218) to fulfill their BSCF requirements should take an additional 21-3xx elective to avoid excessive double counting.*

The Minor in Discrete Mathematics and Logic

This minor develops the fundamentals of discrete mathematics and logic necessary to understand the mathematical foundations of many computer related disciplines. Required courses are:

21-228	Discrete Mathematics [1]	9-12
or 15-251	Great Ideas in Theoretical Computer Science	
21-300	Basic Logic	9
or 15-317	Constructive Logic	
21-301	Combinatorics	9

[1] 21-127 Concepts of Mathematics is a prerequisite for 21-228.

Twenty-seven units of Mathematical Sciences Electives, to be chosen from the following two groups (at least nine units from each group).

Logic		
21-321	Interactive Theorem Proving	9
21-329	Set Theory	9
21-400	Intermediate Logic	9
21-602	Introduction to Set Theory I	12
21-603	Model Theory I	12
80-305	Game Theory	9
80-315	Logics for Knowledge and Belief	9
80-411	Proof Theory	9
80-413	Category Theory	9

Algebra and Discrete Mathematics		
21-341	Linear Algebra	9

21-373	Algebraic Structures	9
21-374	Field Theory	9
21-441	Number Theory	9
21-484	Graph Theory	9
21-610	Algebra I	12
21-701	Discrete Mathematics	12

The Honors Degree Program

This demanding program qualifies the student for an additional degree, the Master of Science in Mathematical Sciences. Admission to the Honors Degree Program is selective and interested students should apply for admission during their junior year. In the application process, the Department will hold to the same high standards which apply to admission to any graduate program. Applicants are not absolutely required to have taken the Mathematical Studies courses and may be admitted on the basis of exceptionally strong performance in non-honors mathematics courses or of accomplishments in research. Applicants are expected to have completed the Mathematical Studies sequences in algebra and analysis or 21-355/21-356 and 21-373/21-341 prior to application. 21-455/21-456 may be taken in place of 21-355/21-356.

In order to complete the Honors Degree Program, students must complete five mathematics graduate courses with grades of B or better and write an honors thesis. At the time of admission, students will declare a timetable on which they plan to take the graduate courses, do the research required for the thesis, and write up their work: this timetable can naturally be adjusted as required. At most, one of these five graduate courses may be applied towards the student's bachelor degree program.

At least three graduate courses must come from the list of Basic Examinations courses (https://www.cmu.edu/math/grad/phd/requirements.html).

Currently these are listed as:

- 21-651 General Topology
- 21-640 Introduction to Functional Analysis
- 21-720 Measure and Integration
- 21-721 Probability
- 21-701 Discrete Mathematics
- 21-737 Probabilistic Combinatorics
- 21-602 Introduction to Set Theory I
- 21-610 Algebra I
- 21-603 Model Theory I
- 21-632 Introduction to Differential Equations

By special permission of the department, one graduate course with sufficient mathematical content offered in another department may be counted. The honors thesis may either be research-based or expository: expository theses must be at a high mathematical level, at least that of a second-year graduate course. Students should plan on finding a thesis advisor by the end of their junior year. Students are required to take 21-901 Master's Degree Research during their senior year, subject to the following conditions:

1. Students must pass a minimum of 15 units of 21-901 to earn the M.S. in Mathematical Sciences.
2. Students who have not defended their thesis by the Add Course Deadline during each of their last two semesters must register for a minimum of three units of 21-901 for that semester.
3. Students may not overload more than 66 units while taking 21-901.

The Master of Science in Mathematical Sciences may be earned together with a bachelor of science from another department.

Faculty

NOHA ABDELGHANY, Assistant Teaching Professor – Ph.D., Western Michigan University; Carnegie Mellon, 2022–

THERESA ANDERSON, Associate Professor – Ph.D., Brown University; Carnegie Mellon, 2022–

JEREMY AVIGAD, Professor – Ph.D., University of California, Berkeley; Carnegie Mellon, 1996–

NICHOLAS BOFFI , Assistant Professor – Ph.D., Harvard University ; Carnegie Mellon, 2024–

THOMAS BOHMAN, Professor – Ph.D., Rutgers University; Carnegie Mellon, 1998–

BORIS BUKH, Professor – Ph.D., Princeton University; Carnegie Mellon, 2012–

CLINTON CONLEY, Associate Professor – Ph.D., University of California Los Angeles; Carnegie Mellon, 2014–

JAMES CUMMINGS, Professor – Ph.D., Cambridge University; Carnegie Mellon, 1996–

HASAN DEMIRKOPARAN, Teaching Professor of Mathematics – Ph.D., Michigan State University; Carnegie Mellon, 2005–

LAYAN EL HAJJ, Associate Teaching Professor – Ph.D., McGill University; Carnegie Mellon, 2023–

CHRISTOPHER EUR, Assistant Professor – Ph.D., University of California, Berkeley; Carnegie Mellon, 2024–

TIMOTHY FLAHERTY, Associate Teaching Professor – Ph.D., University of Pittsburgh; Carnegie Mellon, 1999–

IRENE FONSECA, Kavčić-Moura University Professor of Mathematics – Ph.D., University of Minnesota; Carnegie Mellon, 1987–

FLORIAN FRICK, Associate Professor – Ph.D., Technical University of Berlin; Carnegie Mellon, 2018–

ALAN FRIEZE, Orion Hoch, S 1952, University Professor of Mathematical Sciences – Ph.D., University of London; Carnegie Mellon, 1987–

IRINA GHEORGHICIUC, Associate Teaching Professor – Ph.D., University of Pennsylvania; Carnegie Mellon, 2007–

RAMI GROSSBERG, Professor – Ph.D., Hebrew University of Jerusalem; Carnegie Mellon, 1988–

DAVID HANDRON, Associate Teaching Professor – Ph.D., Rice University; Carnegie Mellon, 1999–

JASON HOWELL, Teaching Professor & Associate Department Head – Ph.D., Clemson University; Carnegie Mellon, 2017–

WILLIAM HRUSA, Professor – Ph.D., Brown University; Carnegie Mellon, 1982–

GAUTAM IYER, Professor – Ph.D., University of Chicago; Carnegie Mellon, 2009–

GREGORY JOHNSON, Associate Teaching Professor – Ph.D., University of Maryland; Carnegie Mellon, 2009–

NIRAJ KHARE, Associate Teaching Professor – Ph.D., Ohio State University; Carnegie Mellon, 2014–

DAVID KINDERLEHRER, Alumni Professor of Mathematical Sciences – Ph.D., University of California at Berkeley; Carnegie Mellon, 1990–

DMITRY KRAMKOV, Mellon College of Science Professor of Mathematical Finance – Ph.D., Steklov Mathematical Institute; Carnegie Mellon, 2000–

MARTIN LARSSON, Professor – Ph.D., Cornell University; Carnegie Mellon, 2019–

GIOVANNI LEONI, Professor – Ph.D., University of Minnesota; Carnegie Mellon, 2002–

PO-SHEN LOH, Professor – Ph.D., Princeton University; Carnegie Mellon, 2009–

JOHN MACKEY, Teaching Professor – Ph.D., University of Hawaii; Carnegie Mellon, 2003–

ROBIN NEUMAYER, Assistant Professor – Ph.D., The University of Texas at Austin; Carnegie Mellon, 2021–

CLIVE NEWSTEAD, Assistant Teaching Professor – PhD, Carnegie Mellon University; Carnegie Mellon, 2018–

DAVID OFFNER, Associate Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2019–

WESLEY PEGDEN, Professor – Ph.D., Rutgers University; Carnegie Mellon, 2013–

AGOSTON PISZTORA, Associate Professor – Ph.D., ETH Zurich; Carnegie Mellon, 1996–

DYLAN QUINTANA, Assistant Teaching Professor – Ph.D., University of Chicago; Carnegie Mellon, 2023–

MATTHEW ROSENZWEIG, Assistant Professor – Ph.D., University of Texas at Austin; Carnegie Mellon, 2023–

ERNEST SCHIMMERLING, Professor – Ph.D., University of California at Los Angeles; Carnegie Mellon, 1998–

MYKHAYLO SHKOLNIKOV, Professor – Ph.D., Stanford University; Carnegie Mellon, 2024–

JONATHAN SIMONE, Assistant Teaching Professor – Ph.D., University of Virginia; Carnegie Mellon, 2024–

DEJAN SLEPČEV, Professor, Mellon College of Science Associate Dean for Faculty and Graduate Affairs – Ph.D., University of Texas at Austin; Carnegie Mellon, 2006–

RICHARD STATMAN, Professor – Ph.D., Stanford University; Carnegie Mellon, 1984–

PRASAD TETALI, Alexander M. Knaster Professor & Department Head – Ph.D., New York University; Carnegie Mellon, 2021–

IAN TICE, Professor – Ph.D., New York University; Carnegie Mellon, 2012–

KONSTANTIN TIKHOMIROV, Associate Professor – Ph.D., University of Alberta; Carnegie Mellon, 2022–

TOMASZ TKOCZ, Associate Professor – Ph.D., University of Warwick; Carnegie Mellon, 2017–

NOEL WALKINGTON, Professor – Ph.D., University of Texas at Austin; Carnegie Mellon, 1989–

ANTHONY WESTON, Associate Teaching Professor – Ph.D., Kent State University; Carnegie Mellon, 2022–

JOHANNES WIESEL, Assistant Professor – DPhil, University of Oxford; Carnegie Mellon, 2023–

ZELEALEM YILMA, Associate Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2015–

MICHAEL YOUNG, Associate Professor & Mellon College of Science Associate Dean for Diversity, Equity and Inclusion – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2021–

Emeriti Faculty

PETER ANDREWS, Professor Emeritus – Ph.D., Princeton University; Carnegie Mellon, 1963–

MANUEL BLUM, University Professor Emeritus – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1999–

DEBORAH BRANDON, Associate Teaching Professor Emerita – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1991–

GÉRARD CORNUÉJOLS, IBM University Professor of Operations Research Emeritus – Ph.D., Cornell University; Carnegie Mellon, 1978–

JOHN LEHOCZKY, Thomas Lord University Professor of Statistics Emeritus – Ph.D., Stanford University; Carnegie Mellon, 1969–

ROY NICOLAIDES, Professor Emeritus – Ph.D., University of London; Carnegie Mellon, 1984–

MARION OLIVER, Teaching Professor Emeritus – Ph.D., Carnegie Mellon University ; Carnegie Mellon, 2004–

DAVID OWEN, Professor Emeritus – Ph.D., Brown University; Carnegie Mellon, 1967–

ROBERT PEGO, Professor Emeritus – Ph.D., University of California at Berkeley; Carnegie Mellon, 2004–

JACK SCHAEFFER, Professor Emeritus – Ph.D., Indiana University; Carnegie Mellon, 1983–

ROBERT SEKERKA, University Professor Emeritus – Ph.D., Harvard University; Carnegie Mellon, 1969–

STEVEN SHREVE, University Professor Emeritus – Ph.D., University of Illinois; Carnegie Mellon, 1980–

SHLOMO TA'ASAN, Professor Emeritus – Ph.D., Weizmann Institute; Carnegie Mellon, 1994–

LUC TARTAR, University Professor of Mathematics Emeritus – Ph.D., University of Paris; Carnegie Mellon, 1987–

RUSSELL WALKER, Teaching Professor Emeritus – D.A., Carnegie Mellon University; Carnegie Mellon, 1984–

WILLIAM WILLIAMS, Professor Emeritus – Ph.D., Brown University; Carnegie Mellon, 1966–

Department of Mathematical Sciences Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

21-020 Calculus Companion Seminar

Fall: 2 units
This is a companion course designed to run alongside 21-120 Differential and Integral Calculus in the fall semesters. Students in this course will be presented with precalculus topics that are necessary for success in 21-120. Students must also be enrolled in 21-120 in order to register for this course.

21-101 Freshman Mathematics Seminar

Intermittent: 3 units
This course is offered in the Fall semester for first semester Freshmen interested in majoring in mathematics. Topics vary from year to year. Recent topics have included Fermat's last theorem, finite difference equations, convexity, and fractals. (Three 50 minute lectures)

21-102 Exploring Modern Mathematics

Fall and Spring: 9 units
This course is designed for non-math majors who are interested in learning some contemporary applications of mathematics with minimal prerequisite math knowledge. The course will survey the mathematical concepts centered along various themes, which may include the mathematics of social choice (voting and apportionment systems), topics in management science (optimization and elementary graph theory), modeling growth systems (population and finance), shape and form (symmetry and fractals), basic applications of probability and counting, and basic applications of number theory (cryptography and coding theory). Additional topics may be presented at the discretion of the instructor.

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-108 Introduction to Mathematical Concepts

Fall and Spring: 6 units
This course is an introduction to the vocabulary necessary for understanding and proving mathematical statements. The topics in this course include integers, rational numbers, polynomials, divisibility of numbers and polynomials, basic logic, sets, relations, functions, rule of sum, and rule of product. (Three 50 minute lectures, two 50 minute recitations)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-111 Calculus I

Fall: 10 units
Review of basic algebra, functions, limits, derivatives of algebraic, exponential and logarithmic functions, curve sketching, maximum-minimum problems. Successful completion of 21-111 and 21-112 entitles a student to enroll in any mathematics course for which 21-120 is a prerequisite. (Three 50 minute lectures, two 50 minute recitations)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-112 Calculus II

Fall and Spring: 10 units
Definite and indefinite integrals, and hyperbolic functions; applications of integration, integration by substitution and by parts. Successful completion of 21-111 and 21-112 entitles a student to enroll in any mathematics course for which 21-120 is a prerequisite. (Three 50 minute lectures, two 50 minute recitations)
Prerequisite: 21-111

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-120 Differential and Integral Calculus

All Semesters: 10 units
Functions, limits, derivatives, logarithmic, exponential, and trigonometric functions, inverse functions; L'Hospital's Rule, curve sketching, Mean Value Theorem, related rates, linear and approximations, maximum-minimum problems, inverse functions, definite and indefinite integrals; integration by substitution and by parts. Applications of integration, as time permits. (Three 50 minute lectures, two 50 minute recitations)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-122 Integration and Approximation

All Semesters: 10 units
Integration by trigonometric substitution and partial fractions; arclength; improper integrals; Simpson's and Trapezoidal Rules for numerical integration; separable differential equations, Newton's method, Euler's method, Taylor's Theorem, including a discussion of the remainder, sequences, series, power series. Parametric curves, polar coordinates, vectors, dot product. (Three 50 minute lectures, two 50 minute recitations)
Prerequisites: 21-112 or 21-120

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-124 Calculus II for Biologists and Chemists

Spring: 10 units
This is intended as a second calculus course for biology and chemistry majors. It uses a variety of computational techniques based around the use of MATLAB or a similar system. Topics to be covered include: Integration: techniques and numerical integration. Ordinary differential equations: techniques for solving ODEs and numerical methods. Modeling with ODEs (e.g., infection, population models). Linear algebra: matrices, complex numbers, eigenvalues, eigenvectors. Systems of ordinary differential equations (if time allows: stability of differential systems). Probability: discrete and continuum probability, conditional probability and independence, limit theorems, important distributions, probabilistic models. (Three 50 minute lectures, two 50 minute recitations)
Prerequisites: 21-120 or 21-112

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-127 Concepts of Mathematics

All Semesters: 12 units
This course introduces the basic concepts, ideas and tools involved in doing mathematics. As such, its main focus is on presenting informal logic, and the methods of mathematical proof. These subjects are closely related to the application of mathematics in many areas, particularly computer science. Topics discussed include a basic introduction to elementary number theory, induction, the algebra of sets, relations, equivalence relations, congruences, partitions, and functions, including injections, surjections, and bijections. A basic introduction to the real numbers, rational and irrational numbers. Supremum and infimum of a set. (Three 50 minute lectures, two 50 minute recitations)
Prerequisites: 21-112 Min. grade C or 15-112 Min. grade C or 21-120 Min. grade C or 21-108 Min. grade C

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-128 Mathematical Concepts and Proofs

Fall: 12 units
This course is intended for MCS first-semester students who are interested in pursuing a major in mathematical sciences. The course introduces the basic concepts, ideas and tools involved in doing mathematics. As such, its main focus in on presenting informal logic, and the methods of mathematical proof. These subjects are closely related to the application of mathematics in many areas, particularly computer science. Topics discussed include a basic introduction to elementary number theory, induction, the algebra of sets, relations, equivalence relations, congruences, partitions, and functions, including injections, surjections, and bijections. A basic introduction to the real numbers, rational and irrational numbers. Supremum and infimum of a set. (Three 50 minute lectures, two 50 minute recitations)
Prerequisites: 15-112 Min. grade C or 21-112 Min. grade C or 21-120 Min. grade C or 21-108 Min. grade C

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-150 Mathematics and the Arts

Intermittent: 9 units
Mathematics and the creative arts have long, interlinked histories. This course touches upon a broad range of mathematical ideas and the writers, artists, and art movements that were influenced and inspired by them. Topics include the use of geometric patterns in Islamic art, the influence of non-Euclidean geometry on Cubism, the constrained writing experiments of the Oulipo, and literary works exploring the concept of infinity.

21-201 Undergraduate Colloquium

Fall and Spring: 1 unit
The purpose of this course is to introduce math majors to the different degree programs in Mathematical Sciences, and to inform math majors about relevant topics such as advising, math courses, graduate schools, and typical career paths in the mathematical sciences. The Career and Professional Development Center will present modules on professional communication, developing interview and networking skills, and preparing for career fairs. (One 50 minute session)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-228 Discrete Mathematics

Fall and Spring: 9 units
The techniques of discrete mathematics arise in every application of mathematics, which is not purely continuous, for example in computer science, economics, and general problems of optimization. This course introduces two of the fundamental areas of discrete mathematics: enumeration and graph theory. The introduction to enumeration includes permutations, combinations, and topics such as discrete probability, combinatorial distributions, recurrence relations, generating functions, Ramsey's Theorem, and the principle of inclusion and exclusion. The introduction to graph theory includes topics such as paths, walks, connectivity, Eulerian and Hamilton cycles, planar graphs, Euler's Theorem, graph coloring, matchings, networks, and trees. (Three 50 minute lectures, one 50 minute recitation)
Prerequisites: 21-128 or 15-151 or 21-127

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-235 Mathematical Studies Analysis I

Fall: 12 units
A component of the honors program, 21-235 is a more demanding version of 21-355 of greater scope. Topics to be covered typically include: metric spaces, normed spaces, and inner product spaces; further properties of metric spaces such as completions, density, compactness, and connectedness; limits and continuity of maps between metric spaces, homeomorphisms, extension theorems, contraction mappings, extreme and intermediate value theorems; convergence of sequences and series of functions; metric spaces of functions, sequences, and metric subsets; Stone-Weierstrass and Arzela-Ascoli theorems; Baire category and applications; infinite series in normed spaces, convergence tests, and power series; differential calculus of maps between normed spaces, inverse and implicit function theorems in Banach spaces; existence results in ordinary differential equations. The prerequisite sequence 21-128, 21-242, 21-269 is particularly recommended. (Three 50 minute lectures, one 50 minute recitation)
Prerequisites: 21-256 or 21-268 or 21-269 or 21-259

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-236 Mathematical Studies Analysis II

Spring: 12 units
A component of the honors program, 21-236 is a more demanding version of 21-356 of greater scope. Topics to be covered typically include: Lebesgue measure in Euclidean space, measurable functions, the Lebesgue integral, integral limit theorems, Fubini-Tonelli theorem, and change of variables; Lebesgue spaces, completeness, approximation, and embeddings; absolutely continuous functions, functions of bounded variation, and curve lengths; differentiable submanifolds of Euclidean space, tangent spaces, mappings between manifolds, vector and tensor fields, manifolds with boundary and orientations; differential forms, integration of forms, Stokes' theorem; Hausdorff measure, divergence theorem. (Three 50 minute lectures, one 50 minute recitation)
Prerequisite: 21-235 Min. grade B

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-237 Mathematical Studies Algebra I

Fall: 12 units
A component of the honors program, 21-237 is a more demanding version of 21-373 (Algebraic Structures) of greater scope. Abstract algebra is the study of algebraic systems by the axiomatic method, and it is one of the core areas of modern mathematics. This course is a rigorous and fast-paced introduction to the basic objects in abstract algebra, focusing on groups and rings. Group-theoretic topics to be covered include: homomorphisms, subgroups, cosets, Lagrange's theorem, conjugation, normal subgroups, quotient groups, isomorphism theorems, automorphism groups, characteristic subgroups, group actions, Cauchy's theorem, Sylow's theorem, normalisers, centralisers, class equation, finite p-groups, permutation and alternating groups, direct and semidirect products, simple groups, subnormal series, the Jordan-Holder theorem. Ring-theoretic topics include: subrings, ideals, quotient rings, isomorphism theorems, polynomial rings, Zorn's Lemma, prime and maximal ideals, prime and irreducible elements, factorization, PIDs and UFDs, Noetherian domains, the Hilbert Basis Theorem, Gauss' lemma and the Eisenstein criterion for irreducibility, fields of fractions, properties of polynomial rings over fields and UFDs, finite fields and applications. The prerequisite sequence of 21-128, 21-242, 21-269 is particularly recommended. (Three 50 minute lectures, one 50 minute recitation)
Prerequisites: (21-128 or 21-127 or 15-151) and (21-269 or 21-268) and (21-241 or 21-242)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-238 Mathematical Studies Algebra II

Spring: 12 units
A component of the honors program, 21-238 is a more demanding version of 21-341 (Linear Algebra) of greater scope. Linear algebra is a crucial tool in pure and applied mathematics. This course aims to introduce the main ideas at a high level of rigour and generality. The course covers vector spaces over arbitrary fields and the natural generalization to modules over rings. Vector space topics to be covered include: fields, Zorn's Lemma, vector spaces (possibly infinite dimensional) over an arbitrary field, independent sets, bases, existence of a basis, exchange lemma, dimension. Linear transformations, dual space, multilinear maps, tensor products, exterior powers, the determinant, eigenvalues, eigenvectors, characteristic and minimal polynomial of a transformation, the Cayley-Hamilton theorem. Module-theoretic topics to be covered include: review of (commutative) rings, R-modules, sums and quotients of modules, free modules, the structure theorem for finitely generated modules over a PID, Jordan and rational canonical forms, structure theory of finitely generated abelian groups. Further topics in real and complex inner product spaces include: orthonormal sets, orthonormal bases, the Gram-Schmidt process, symmetric/Hermitian operators, orthogonal/unitary operators, the spectral theorem, quadratic forms, the singular value decomposition. Possible additional topics: applications to combinatorics, category theory, representations of finite groups, unitary representations of infinite groups. (Three 50 minute lectures, one 50 minute recitation)
Prerequisite: 21-237 Min. grade B

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-240 Matrix Algebra with Applications

Fall and Spring: 10 units
Vectors and matrices, the solution of linear systems of equations, vector spaces and subspaces, orthogonality, determinants, real and complex eigenvalues and eigenvectors, linear transformations. The course is intended for students in Economics, Statistics, Information Systems, and it will focus on topics relevant to these fields. (Three 50 minute lectures, one 50 minute recitation)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-241 Matrices and Linear Transformations

All Semesters: 11 units
A first course in linear algebra intended for scientists, engineers, mathematicians and computer scientists. Students will be required to write some straightforward proofs. Topics to be covered: complex numbers, real and complex vectors and matrices, rowspace and columnspace of a matrix, rank and nullity, solving linear systems by row reduction of a matrix, inverse matrices and determinants, change of basis, linear transformations, inner product of vectors, orthonormal bases and the Gram-Schmidt process, eigenvectors and eigenvalues, diagonalization of a matrix, symmetric and orthogonal matrices. 21-127 is strongly recommended. (Three 50 minute lectures, two 50 minute recitations)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-242 Matrix Theory

Fall: 11 units
A component of the honors program, 21-242 is a more demanding version of 21-241 (Matrix Algebra and Linear Transformations), of greater scope, with increased emphasis placed on rigorous proofs. Topics to be covered: complex numbers, real and complex vectors and matrices, rowspace and columnspace of a matrix, rank and nullity, solving linear systems by row reduction of a matrix, inverse matrices and determinants, change of basis, linear transformations, inner product of vectors, orthonormal bases and the Gram-Schmidt process, eigenvectors and eigenvalues, diagonalization of a matrix, symmetric and orthogonal matrices, hermitian and unitary matrices, quadratic forms. (Three 50 minute lectures, two 50 minute recitations)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-254 Linear Algebra and Vector Calculus for Engineers

Fall and Spring: 11 units
This course will introduce the fundamentals of vector calculus and linear algebra. The topics include vector and matrix operations, determinants, linear systems, matrix eigenvalue problems, vector differential calculus including gradient, divergence, curl, and vector integral calculus including line, surface, and volume integral theorems. Lecture and assignments will emphasize the applications of these topics to engineering problems. (Three 50 minute lectures, one 50 minute recitation)
Prerequisite: 21-122

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-256 Multivariate Analysis

Fall and Spring: 9 units
This course is designed for students in Economics or Business Administration. Matrix algebra: vectors, matrices, systems of equations, dot product, cross product, lines and planes. Optimization: partial derivatives, the chain rule, gradient, unconstrained optimization, constrained optimization (Lagrange multipliers and the Kuhn-Tucker Theorem). Improper integrals. Multiple integration: iterated integrals, probability applications, triple integrals, change of variables. (Three 50 minute lectures, one 50 minute recitation)
Prerequisites: 21-112 or 21-120

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-257 Models and Methods for Optimization

Intermittent: 9 units
Introduces basic methods of operations research and is intended primarily for Business Administration and Economics majors. Review of linear systems; linear programming, including the simplex algorithm, duality, and sensitivity analysis; the transportation problem; the critical path method; the knapsack problem, traveling salesman problem, and an introduction to set covering models. (Three 50 minute lectures, one 50 minute recitation)
Prerequisites: 21-241 or 21-242 or 21-256 or 18-202 or 06-262 or 21-240

21-259 Calculus in Three Dimensions

All Semesters: 10 units
Vectors, lines, planes, quadratic surfaces, polar, cylindrical and spherical coordinates, partial derivatives, directional derivatives, gradient, divergence, curl, chain rule, maximum-minimum problems, multiple integrals, parametric surfaces and curves, line integrals, surface integrals, Green-Gauss theorems. (Three 50 minute lectures, two 50 minute recitations)
Prerequisite: 21-122

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-260 Differential Equations

All Semesters: 9 units
Ordinary differential equations: first and second order equations, applications, Laplace transforms; partial differential equations: partial derivatives, separation of variables, Fourier series; systems of ordinary differential equations; applications. 21-259 or 21-268 or 21-269 are recommended. (Three 50 minute lectures, one 50 minute recitation)
Prerequisite: 21-122

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-261 Introduction to Ordinary Differential Equations

Spring: 10 units
A first course in ordinary differential equations intended primarily for math majors and for those students interested in a more conceptual treatment of the subject. One of the goals of this course is to prepare students for upper level courses on differential equations, mathematical analysis and applied mathematics. Students will be required to write rigorous arguments. Topics to be covered: Ordinary differential equations: first and second order equations, applications, Laplace transform, systems of linear ordinary differential equations; systems of nonlinear ordinary differential equations, equilibria and stability, applications. Corequisites: (21-268 or 21-269 or 21-259) and (21-241 or 21-242). (Three 50 minute lectures, one 50 minute recitation)
Prerequisite: 21-122

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-266 Vector Calculus for Computer Scientists

Spring: 10 units
This course is an introduction to vector calculus making use of techniques from linear algebra. Topics covered include scalar-valued and vector-valued functions, conic sections and quadric surfaces, new coordinate systems, partial derivatives, tangent planes, the Jacobian matrix, the chain rule, gradient, divergence, curl, the Hessian matrix, linear and quadratic approximation, local and global extrema, Lagrange multipliers, multiple integration, parametrised curves, line integrals, conservative vector fields, parametrised surfaces, surface integrals, Green's theorem, Stokes's theorem and Gauss's theorem. (Three 50 minute lectures, one 50 minute recitation)
Prerequisites: 21-122 and (21-242 or 21-241 Min. grade C)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-268 Multidimensional Calculus

Spring: 11 units
A serious introduction to multidimensional calculus that makes use of matrices and linear transformation. Results will be stated carefully and rigorously. Students will be expected to write some proofs; however, some of the deeper results will be presented without proofs. Topics to be covered include: functions of several variables, regions and domains, limits and continuity, partial derivatives, linearization and Jacobian matrices, chain rules, inverse and implicit functions, geometric applications, higher derivatives, Taylor's theorem, optimization, vector fields, multiple integrals and change of variables, Leibnitz's rule, line integrals, Green's theorem, path independence and connectedness, conservative vector fields, surfaces and orientability, surface integrals, divergence theorem and Stokes's theorem. (Three 50 minute lectures, two 50 minute recitations)
Prerequisites: 21-122 and (21-241 or 21-242) and (15-151 or 21-128 or 21-127)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-269 Vector Analysis

Spring: 12 units
A component of the honors program, 21-269 is a more demanding version of 21-268 of greater scope, with greater emphasis placed on rigorous proofs. Topics to be covered typically include: the real field, sups, infs, and completeness; geometry and topology of metric spaces; limits, continuity, and derivatives of maps between normed spaces; inverse and implicit function theorems, higher derivatives, Taylor's theorem, extremal calculus, and Lagrange multipliers. Integration. Iterated integration and change of variables. (Three 50 minute lectures, two 50 minute recitations)
Prerequisites: 21-242 Min. grade B or 21-241 Min. grade A

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-270 Introduction to Mathematical Finance

Spring: 9 units
This is a first course for those considering majoring or minoring in Computational Finance. The theme of this course is pricing derivative securities by replication. The simplest case of this idea, static hedging, is used to discuss net present value of a non-random cash flow, internal rate of return, and put-call option parity. Pricing by replication is then considered in a one-period random model. Risk-neutral probability measures, the Fundamental Theorems of Asset Pricing, and an introduction to expected utility maximization and mean-variance analysis are presented in this model. Finally, replication is studied in a multi-period binomial model. Within this model, the replicating strategies for European and American options are determined. (Three 50 minute lectures)
Prerequisites: 21-112 or 21-120

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-292 Operations Research I

Spring: 9 units
Operations research offers a scientific approach to decision making, most commonly involving the allocation of scarce resources. This course develops some of the fundamental methods used. Linear programming: the simplex method and its linear algebra foundations, duality, post-optimality and sensitivity analysis; the transportation problem; the critical path method; non-linear programming methods. (Three 50 minute lectures, one 50 minute recitation)
Prerequisites: 21-122 and (21-242 or 21-241 or 21-240) and (21-228 or 15-251)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-295 Putnam Seminar

Fall: 3 units
A problem solving seminar designed to prepare students to participate in the annual William Lowell Putnam Mathematical Competition. Students solve and present their solutions to problems posed. (One 50 minute session)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-300 Basic Logic

Fall: 9 units
Propositional and predicate logic: Syntax, proof theory and semantics up to completeness theorem, Lowenheim Skolem theorems, and applications of the compactness theorem. (Three 50 minute lectures)
Prerequisites: 21-228 or 21-373 or 15-251

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-301 Combinatorics

Fall and Spring: 9 units
A major part of the course concentrates on algebraic methods, which are relevant in the study of error correcting codes, and other areas. Topics covered in depth include permutations and combinations, generating functions, recurrence relations, the principle of inclusion and exclusion, and the Fibonacci sequence and the harmonic series. Additional topics may include existence proofs, partitions, finite calculus, generating combinatorial objects, Polya theory, codes, probabilistic methods. (Three 50 minute lectures)
Prerequisites: 21-122 and (21-228 or 15-251)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-302 Lambda Calculus

Intermittent: 9 units
An introductory course in classical lambda calculus, with an emphasis on syntax. The course will describe many research problems which are suitable topics for senior theses or master's theses. Topics will include: Basic properties of reduction and conversion; Reduction and conversion strategies; Calculability and representation of data types; Elementary theory of Ershov numberings; Bohm's theorem, easy terms, and other exotic combinations; Solvability of functional equations (unification); Combinatorics and bases; Simple and algebraic types; Labelled reduction and intersection types; Extensionality and the omega rule.
Prerequisites: 15-150 or 21-300 or 80-310

21-321 Interactive Theorem Proving

Fall: 9 units
Computational proof assistants now make it possible to work interactively to write mechanically verified definitions, theorems, and proofs. Important theorems have been formalized in this way, and digital libraries are being developed collaboratively by the mathematical community. Formalization of mathematics also serves as a gateway to the use of new technologies for discovery, such as automated reasoning and machine learning. This course will teach you how to formalize mathematics so that you, too, can contribute to the effort. We will explore a logical framework, dependent type theory, which serves as a practical foundation in a number of proof assistants. Finally, as time allows, we will explore ways of automating various aspects of mathematical reasoning. (Three 50 minute lectures)
Prerequisites: 21-128 or 21-127 or 15-151

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-322 Topics in Formal Mathematics

Intermittent: 9 units
Complementary to 21-321 Interactive Theorem Proving, this course is designed to present special topics on the use of formalization and formal methods in mathematics. For example, the course might focus on formalization of a specific branch of mathematics, or on a specific method for automation or computational reasoning.
Prerequisites: (21-128 or 21-127 or 15-151) and (21-259 or 21-266 or 21-268 or 21-269)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-325 Probability

Fall and Spring: 9 units
This course focuses on the understanding of basic concepts in probability theory and illustrates how these concepts can be applied to develop and analyze a variety of models arising in computational biology, finance, engineering and computer science. The firm grounding in the fundamentals is aimed at providing students the flexibility to build and analyze models from diverse applications as well as preparing the interested student for advanced work in these areas. The course will cover core concepts such as probability spaces, random variables, random vectors, multivariate densities, distributions, expectations, sampling and simulation; independence, conditioning, conditional distributions and expectations; limit theorems such as the strong law of large numbers and the central limit theorem; as well as additional topics such as large deviations, random walks and Markov chains, as time permits. (Three 50 minute lectures)
Prerequisites: 21-269 or 21-268 or 21-256 or 21-259

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-329 Set Theory

Spring: 9 units
Set theory was invented about 110 years ago by George Cantor as an instrument to understand infinite objects and to compare different sizes of infinite sets. Since then set theory has come to play an important role in several branches of modern mathematics, and serves as a foundation of mathematics. Contents: Basic properties of natural numbers, countable and uncountable sets, construction of the real numbers, some basic facts about the topology of the real line, cardinal numbers and cardinal arithmetic, the continuum hypothesis, well ordered sets, ordinal numbers and transfinite induction, the axiom of choice, Zorn's lemma. Optional topics if time permits: Infinitary combinatorics, filters and large cardinals, Borel and analytic sets of reals. (Three 50 minute lectures)
Prerequisites: 15-151 or 21-127 or 21-128

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-341 Linear Algebra

Fall and Spring: 9 units
A mathematically rigorous treatment of Linear Algebra over an arbitrary field. Topics studied will include abstract vector spaces, linear transformations, determinants, eigenvalues, eigenvectors, inner products, invariant subspaces, canonical forms, the spectral theorem and the singular value decomposition. 21-373 recommended. (Three 50 minute lectures)
Prerequisites: (21-241 or 21-242) and 21-373

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-344 Numerical Linear Algebra

Spring: 9 units
An introduction to algorithms pertaining to matrices and large linear systems of equations. Direct methods for large sparse problems including graph data structures, maximum matchings, row and column orderings, and pivoting strategies. Iterative methods including Conjugate Gradient and GMRES, with a discussion of preconditioning strategies. Additional topics include: computation of eigenvalues and eigenvectors, condition numbers, the QR and singular value decompositions, least-squares systems. (Three 50 minute lectures)
Prerequisites: 15-112 and (21-242 or 21-241 or 21-240) and (21-269 or 21-259 or 21-268)

21-355 Principles of Real Analysis I

Fall and Spring: 9 units
This course provides a rigorous and proof-based treatment of functions of one real variable. The course presumes some mathematical sophistication including the ability to recognize, read, and write proofs. Topics include: The Real Number System: Field and order axioms, sups and infs, completeness. Real Sequences. Bolzano-Weierstrass theorem. Topology of the Real Line: Open sets, closed sets, compactness, Heine-Borel Theorem. Continuity: extreme and intermediate value theorems, uniform continuity. Differentiation: chain rule, local extrema, mean-value theorem, L'Hospital's rule, Taylor's theorem. Riemann integration: sufficient conditions for integrability, fundamental theorems of calculus. (Three 50 minute lectures)
Prerequisites: (15-151 or 21-128 or 21-127) and 21-122

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-356 Principles of Real Analysis II

Fall and Spring: 9 units
This course provides a rigorous and proof-based treatment of functions of several real variables. The course presumes some mathematical sophistication including the ability to recognize, read, and write proofs. Topics include: Metric spaces. Differential calculus in Euclidean spaces: continuity, differentiability, partial derivatives, gradients, differentiation rules, implicit and inverse function theorems. Multiple integrals. Integration on curves and hypersurfaces: arclength, and generalized area. The divergence theorem and the 3D Stokes theorem. Regarding prerequisites, 21-268 or 21-269 are strongly recommended rather than 21-259. (Three 50 minute lectures)
Prerequisites: (21-269 or 21-268 or 21-259) and (21-242 or 21-241) and (21-355 or 21-455)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-360 Differential Geometry of Curves and Surfaces

Intermittent: 9 units
The course is a rigorous introduction to the differential and integral calculus of curves and surfaces. Topics to be covered include: Parameterized and regular curves Frenet equations canonical coordinate system, local canonical forms, global properties of plane curves Regular surfaces, differential functions on surfaces, the tangent plane and differential of a map, orientation of surfaces, characterization of compact orientable surfaces, classification of compact surfaces The geometry of the Gauss map, isometries and conformal maps, parallel transport, geodesics, the Gauss-Bonnet theorem and applications. More topics may be covered, as time allows. Students should be prepared to write proofs and perform computations. 21-356 or 21-236 are recommended. (Three 50 minute lectures)
Prerequisites: 21-269 or 21-268

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-365 Projects in Applied Mathematics

Intermittent: 9 units
This course provides students with an opportunity to solve problems posed by area companies. It is also designed to provide experience working as part of a team to solve problems for a client. The background needed might include linear programming, simulation, data analysis, scheduling, numerical techniques, etc.

21-366 Topics in Applied Mathematics

Intermittent: 9 units
This course affords students with the opportunity to study topics which are in the area of expertise of the instructor. This course may taken more than once if content is sufficiently different. Course prerequisites will depend on the content of the course. Please see the course URL for semester-specific topics. (Three 50 minute lectures)
Prerequisite: 21-228

Course Website: https://www.cmu.edu/math/courses/special-topics.html

21-369 Numerical Methods

Fall and Spring: 12 units
This course provides an introduction to the use of computers to solve scientific problems. Methods for the computational solution of linear algebra systems, nonlinear equations, the interpolation and approximation of functions, differentiation and integration, and ordinary differential equations. Analysis of roundoff and discretization errors and programming techniques. 21-268 or 21-269 are recommended prerequisites, rather than 21-259. (Three 50 minute lectures, one 50 minute recitation)
Prerequisites: (15-110 or 15-112) and (21-269 or 21-268 or 21-259) and (21-242 or 21-241 or 21-240 or 33-232) and (21-261 or 21-630 or 21-260 or 33-231)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-370 Discrete Time Finance

Fall: 9 units
This course introduces the Black-Scholes option pricing formula, shows how the binomial model provides a discretization of this formula, and uses this connection to fit the binomial model to data. It then sets the stage for Continuous-Time Finance by discussing in the binomial model the mathematical technology of filtrations, martingales, Markov processes and risk-neutral measures. Additional topics are American options, expected utility maximization, the Fundamental Theorems of Asset Pricing in a multi-period setting, and term structure modeling, including the Heath-Jarrow-Morton model. Students in 21-370 are expected to read and write proofs. Acceptable corequisites include 21-325 or 36-225 (Three 50 minute lectures)
Prerequisites: (21-270 or 70-492) and (21-269 or 21-259 or 21-256 or 21-268)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-371 Functions of a Complex Variable

Fall: 9 units
This course provides an introduction to one of the basic topics of both pure and applied mathematics and is suitable for those with both practical and theoretical interests. Algebra and geometry of complex numbers; complex differentiation and integration. Cauchy's theorem and applications; conformal mapping; applications. 21-268 or 21-269 are recommended prerequisites, rather than 21-259. (Three 50 minute lectures)
Prerequisites: 21-355 or 21-455 or 21-235

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-373 Algebraic Structures

Fall and Spring: 9 units
Groups: Homomorphisms. Subgroups, cosets, Lagrange's theorem. Conjugation. Normal subgroups, quotient groups, first isomorphism theorem. Group actions, Cauchy's Theorem. Dihedral and alternating groups. The second and third isomorphism theorems. Rings: Subrings, ideals, quotient rings, first isomorphism theorem. Polynomial rings. Prime and maximal ideals, prime and irreducible elements. PIDs and UFDs. Noetherian domains. Gauss' lemma. Eisenstein criterion. Fields: Field of fractions of an integral domain. Finite fields. Applications to coding theory, cryptography, number theory. (Three 50 minute lectures)
Prerequisites: (15-151 or 21-128 or 21-127) and (21-242 or 21-241)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-374 Field Theory

Spring: 9 units
The purpose of this course is to provide a successor to Algebraic Structures, with an emphasis on applications of groups and rings within algebra to some major classical problems. These include constructions with a ruler and compass, and the solvability or unsolvability of equations by radicals. It also offers an opportunity to see group theory and basic ring theory "in action", and introduces several powerful number theoretic techniques. The basic ideas and methods required to study finite fields will also be introduced. These ideas have recently been applied in a number of areas of theoretical computer science including primality testing and cryptography. (Three 50 minute lectures)
Prerequisite: 21-373

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-375 Topics in Algebra

Intermittent: 9 units
Typical of courses that might be offered from time to time are elliptic curves, commutative algebra, and theory of Boolean functions. (Three 50 minute lectures)
Prerequisite: 21-373

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-377 Monte Carlo Simulation for Finance

Intermittent: 9 units
first course in Monte Carlo simulation, with applications to Mathematical Finance. Students will put into practice many of the theoretical ideas introduced in Continuous Time Finance. Topics to be covered: random variable/stochastic process generation; options pricing; variance reduction; Markov chain Monte Carlo Methods.
Prerequisites: 21-420 or 21-325 Min. grade B

21-378 Mathematics of Fixed Income Markets

Fall: 9 units
A first course in fixed income. Students will be introduced to the most common securities traded in fixed income markets and the valuation methods used to price them. Topics covered include discount factors; interest rates basics; pricing of coupon bonds; identifying the yield to maturity, as well as bond sensitivities to interest rates; term structure modeling; forward and swap rates; fixed income derivatives (including mortgage backed securities) and their valuation through backwards induction; fixed income indexes and return attribution. For a co-requisite, 36-225 can be accepted as an alternative for 21-325. (Three 50 minute lectures)
Prerequisite: 21-270 Min. grade B

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-380 Introduction to Mathematical Modeling

Intermittent: 9 units
This course shall examine mathematical models, which may be used to describe natural phenomena. Examples, which have been studied include: continuum description of highway traffic, discrete velocity models of a monotonic gas, chemotactic behavior in biological systems, European options pricing, and cellular-automata. Systems such as the first four are described by partial differential equations; the last involves discrete-time and discrete-phase dynamical systems, which have been used to successfully represent both physical and biological systems. The course will develop these models and then examine the behavior of the underlying systems, both analytically and numerically. The mathematical tools required will be developed in the course. (Three 50 minute lectures)
Prerequisites: (21-241 or 21-242) and (21-261 or 21-260)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-387 Monte Carlo Methods and Applications

Intermittent: 9 units
The Monte Carlo method uses random sampling to solve computational problems that would otherwise be intractable, and enables computers to model complex systems in nature that are otherwise too difficult to simulate. This course provides a first introduction to Monte Carlo methods from complementary theoretical and applied points of view, and will include implementation of practical algorithms. Topics include random number generation, sampling, Markov chains, Monte Carlo integration, stochastic processes, and applications in computational science. Students need a basic background in probability, multivariable calculus, and some coding experience in any language. (Two 80 minute lectures)
Prerequisites: (21-259 Min. grade C or 21-269 Min. grade C or 21-266 Min. grade C or 21-268 Min. grade C) and (36-235 Min. grade C or 15-259 Min. grade C or 36-225 Min. grade C or 36-219 Min. grade C or 21-325 Min. grade C or 18-465 Min. grade C or 36-218 Min. grade C)

Course Website: http://www.cs.cmu.edu/~kmcrane/random/

21-393 Operations Research II

Fall: 9 units
Building on an understanding of Linear Programming developed in 21-292 Operations Research I, this course introduces more advanced topics. Integer programming, including cutting planes and branch and bound. Dynamic programming. An introduction to Combinatorial Optimization including optimal spanning trees, shortest paths, the assignment problem and max-flow/min-cut. The traveling salesman problem and NP-completeness. An important goal of this course is for the student to gain experience with the process of working in a group to apply operations research methods to solve a problem. A portion of the course is devoted to a group project based upon case studies and the methods presented. 36-410 recommended. (Three 50 minute lectures)
Prerequisites: (15-251 or 21-228) and 21-292

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-400 Intermediate Logic

Intermittent: 9 units
The course builds on the proof theory and model theory of first-order logic covered in 21-300. These are applied in 21-400 to Peano Arithmetic and its standard model, the natural numbers. The main results are the incompleteness, undefinability and undecidability theorems of Godel, Tarski, Church and others. Leading up to these, it is explained how logic is formalized within arithmetic, how this leads to the phenomenon of self-reference, and what it means for the axioms of a theory to be computably enumerable. Related aspects of computability theory are included to the extent that time permits. (Three 50 minute lectures)
Prerequisite: 21-300

21-410 Research Topics in Mathematical Sciences

Intermittent: 9 units
This course affords undergraduates to pursue elementary research topics in the area of expertise of the instructor. The prerequisites will depend on the content of the course. (Three 50 minute lectures)

Course Website: https://www.cmu.edu/math/courses/special-topics.html

21-420 Continuous-Time Finance

Spring: 9 units
This course begins with Brownian motion, stochastic integration,and Ito's formula from stochastic calculus. This theory is used to develop the Black-Scholes option pricing formula and the Black-Scholes partial differential equation. Additional topics may include models of credit risk, simulation, and expected utility maximization. (Three 50 minute lectures)
Prerequisites: (21-260 or 18-202) and 21-370 and (36-225 or 36-217 or 15-259 or 36-218 or 21-325)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-435 Applied Harmonic Analysis

Intermittent: 9 units
This course serves as a broad introduction to harmonic analysis and its applications, particularly in 1-dimensional signal processing and in image processing, for undergraduate students in mathematics, engineering, and the applied sciences. Topics include: Discrete Fourier transform and fast Fourier transform; Fourier series and the Fourier transform; Hilbert spaces and applications; Shannon sampling theorem, bandlimited functions, uncertainty principle; Wavelets and multi-resolution analysis; Applications in image processing. (Three 50 minute lectures)
Prerequisites: (21-355 or 21-235 or 21-455) and (21-242 or 21-241)

21-441 Number Theory

Fall: 9 units
Number theory deals with the integers, the most basic structures of mathematics. It is one of the most ancient, beautiful, and well-studied branches of mathematics, and has recently found surprising new applications in communications and cryptography. Course contents: Structure of the integers, greatest common divisors, prime factorization. Modular arithmetic, Fermat's Theorem, Chinese Remainder Theorem. Number theoretic functions, e.g. Euler's function, Mobius functions, and identities. Diophantine equations, Pell's Equation, continued fractions. Modular polynomial equations, quadratic reciprocity. (Three 50 minute lectures)
Prerequisites: (21-242 or 21-241) and 21-373

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-455 Intermediate Real Analysis I

Fall: 12 units
This course provides a rigorous and proof-based treatment of the general theory of functions on metric spaces. The course serves as a more advanced version of 21-355 Principles of Real Analysis and is primarily intended for students who have taken 21-269. Topics include: Metric spaces: Completeness, density, separability, compactness, connectedness. Baire theorem and applications. Contraction maps: fixed points, applications, inverse, and implicit function theorems. Spaces of functions: uniform and pointwise convergence, Stone-Weierstrass theorem, Arzela-Ascoli theorem. (Three 50 minute lectures, one 50 minute recitation)
Prerequisites: 21-269 or 21-268

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-456 Intermediate Real Analysis II

Spring: 10 units
This course provides a rigorous and proof-based treatment of the general theory of functions on Euclidean spaces. The course serves as a more advanced version of 21-356 Principles of Real Analysis II and is primarily intended for students who have taken 21-455. Topics include: Lebesgue integration in Euclidean spaces: Lebesgue measure and Lebesgue integration, convergence and integration theorems, Fubini's theorem, change of variables. Curves, arclength, curve integrals. Submanifolds of Euclidean space: applications of the inverse and implicit function theorems, tangent space, normal space, orientation, integration on manifolds. Theorems of vector calculus: divergence theorem, Stokes theorem in 3D. (Three 50 minute lectures, one 50 minute recitations)
Prerequisites: 21-455 or 21-355 or 21-235

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-465 Topology

Intermittent: 9 units
Metric spaces. Topological spaces. Separation axioms. Open, closed and compact sets. Continuous functions. Product spaces, subspaces, quotient spaces. Connectedness and path-connectedness. Homotopy. Fundamental group of a pointed space. Simply connected spaces. Winding number, the fundamental group of the circle. Functorial property of the fundamental group. Brouwer fixed point theorem. Covering spaces. van Kampen's theorem. 2-manifolds. Triangulations. Euler characteristic. Surgery, classification of compact 2-manifolds. (Three 50 minute lectures)
Prerequisites: (21-455 or 21-355 or 21-235) and 21-373

21-469 Computational Introduction to Partial Differential Equations

Intermittent: 12 units
A Partial Differential Equation (PDE for short) is a differential equation involving derivatives with respect to more than one variable. These arise in numerous applications from various disciplines. Most PDEs do not have explicit solutions, and hence computational methods are essential for understanding the underlying phenomena. This course will serve as a first introduction to PDEs and their numerical approximation, and will focus on a variety of mathematical models. It will cover both analytical methods, numerical methods (e.g. finite differences) and the use of a computer to approximate and visualize solutions. The mathematical ideas behind phenomena observed in nature will be studied at the theoretical level and in numerical simulations (e.g. speed of wave propagation, and/or shocks in traffic flow). Topics will include: Derivation of PDEs from physical principles, analytical and computational tools for the transport equation and the Poisson equation, Fourier analysis, analytical and numerical techniques for the solution of parabolic equations and if time permits, the wave equation. (Three 50 minute lectures, one 80 minute recitation)
Prerequisites: (21-240 or 21-242 or 21-241) and (21-269 or 21-268 or 21-259) and (21-261 or 33-231 or 21-260 or 21-630) and (15-112 or 15-110)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-470 Selected Topics in Analysis

Intermittent: 9 units
Typical of courses, which are offered from time to time are finite difference equations, calculus of variations, and applied control theory. The prerequisites will depend on the content of the course. (Three 50 minute lectures)
Prerequisites: 21-260 and 21-241 and 21-259

21-476 Introduction to Dynamical Systems

Intermittent: 9 units
This course is an introduction to differentiable dynamical systems. The material includes basic properties of dynamical systems, including the existence and uniqueness theory, continuation, singular points, orbits, and their classification. The Poincare'-Bendixson theorem and typical applications, like Lienard equations and Lotka-Volterra are also covered. An introduction to chaos as time permits. (Three 50 minute lectures)
Prerequisites: (21-241 or 21-242) and 21-261

21-484 Graph Theory

Spring: 9 units
Graph theory uses basic concepts to approach a diversity of problems and nontrivial applications in operations research, computer science and other disciplines. It is one of the very few mathematical areas where one is always close to interesting unsolved problems. Topics include graphs and subgraphs, trees, connectivity, Euler tours and Hamilton cycles, matchings, graph colorings, planar graphs and Euler's Formula, directed graphs, network flows, counting arguments, and graph algorithms. (Three 50 minute lectures)
Prerequisites: (15-251 or 21-228) and (21-241 or 21-242)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-590 Practicum in Mathematical Sciences

All Semesters: 3 units
Students in this course gain experience with the application of mathematical models to business and/or industrial problems during an internship. The internship is set up by the student in consultation with a faculty member. The students must also have a mentor at the firm providing the internship, who together with the faculty member develops a description of the goals of the internship. The internship must include the opportunity to learn about problems which have mathematical content. Tuition is charged for this course.

21-599 Undergraduate Reading and Research

Fall and Spring
Individual reading courses or projects in mathematics and its applications. Prerequisites and units to be negotiated with individual instructors.

21-602 Introduction to Set Theory I

Fall: 12 units
The axioms of ZFC, ordinal arithmetic, cardinal arithmetic including Konig's lemma, class length induction and recursion, the rank hierarchy, the Mostowski collapse theorem, the H-hierarchy, the Delta_1 absoluteness theorem, the absoluteness of wellfoundedness, the reflection theorem for hierarchies of sets, ordinal definability, the model HOD, relative consistency, Goedel's theorem that HOD is a model of ZFC, constructibility, Goedel's theorem that L is a model of ZFC + GCH, the Borel and Projective hierarchies and their effective versions, Suslin representations for Sigma^1_1, Pi^1_1 and Sigma^1_2, sets of reals, Shoenfield's absoluteness theorem, the complexity of the set of constructible reals, the combinatorics of club and stationary sets (including the diagonal intersection, the normality of the club filter, Fodor's lemma and its applications), Solovay's splitting theorem, model theoretic techniques commonly applied in set theory (e.g., elementary substructures, chains of models and ultrapowers), club and stationary subsets of [X]^/omega and their combinatorics, Jensen's diamond principles and his proofs that they hold in L, Gregory's theorem and generalizations, constructions of various kinds of uncountable trees (including Aronszajn, special, Suslin, Kurepa), Jensen's square principles and elementary applications, the basic theory of large cardinals (including inaccesssible, Mahlo, weakly compact and measurable cardinals), Scott's theorem that there are no measurable cardinals in L, Kunen's theorem that the only elementary embedding from V to V is the identity. Optional topic: SCH and Silver's theorem. (Three 50 minute lectures)
Prerequisites: (21-355 Min. grade B or 21-455 Min. grade B or 21-235 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B) and 21-329 Min. grade B and 21-300 Min. grade B

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-603 Model Theory I

Intermittent: 12 units
Similarity types, structures; downward Lowenheim Skolem theorem; construction of models from constants, Henkin's omitting types theory, prime models; elementary chains of models, basic two cardinal theorems, saturated models, basic results on countable models including Ryll-Nardzewski's theorem; indiscernible sequences, Ehrenfeucht-Mostowski models; introduction to stability, rank functions, primary models, and a proof of Morley's catagoricity theorem; basic facts about infinitary languages, computation of Hanf-Morley numbers. (Three 50 minute lectures)
Prerequisites: (21-455 Min. grade B or 21-235 Min. grade B or 21-355 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

21-604 Introduction to Recursion Theory

Intermittent: 12 units
Models of computation, computable functions, solvable and unsolvable problems, reducibilities among problems, recursive and recursively enumerable sets, the recursion theorem, Post's problem and the Friedberg-Muchnik theorem, general degrees and r.e. degrees, the arithmetical hierarchy, the hyper-arithmetical hierarchy, the analytical hierarchy, higher type recursion. (Three 50 minute lectures)
Prerequisites: (21-455 Min. grade B or 21-235 Min. grade B or 21-355 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

21-610 Algebra I

Intermittent: 12 units
The structure of finitely generated abelian groups, the Sylow theorems, nilpotent and solvable groups, simplicity of alternating and projective special linear groups, free groups, the Neilsen-Schreier theorem. Vector spaces over division rings, field extensions, the fundamental Galois correspondence, algebraic closure. The Jacobson radical and the structure of semisimple rings. Time permitting, one of the following topics will be included: Wedderburn's theorem on finite division rings, Frobenius' Theorem. Prerequisite: Familiarity with the content of an undergraduate course on groups and rings. (Three 50 minute lectures)
Prerequisites: (21-355 Min. grade B or 21-235 Min. grade B or 21-455 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-620 Real Analysis

Fall: 6 units
A review of one-dimensional, undergraduate analysis, including a rigorous treatment of the following topics in the context of real numbers: sequences, compactness, continuity, differentiation, Riemann integration. (Mini-course. Normally taken with 21-621.) (Three 50 minute lectures)
Prerequisites: (21-455 Min. grade B or 21-235 Min. grade B or 21-355 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

21-621 Introduction to Lebesgue Integration

Fall: 6 units
Construction of Lebesgue measure and the Lebesgue integral on the real line. Fatou's Lemma, the monotone convergence theorem, the dominated convergence theorem. (Mini-course. Normally taken with 21-620.) (Three 50 minute lectures)
Prerequisites: (21-235 Min. grade B or 21-355 Min. grade B or 21-455 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B) and 21-620 Min. grade B

21-623 Complex Analysis

Intermittent: 12 units
The complex plane, holomorphic functions, power series, complex integration, and Cauchy's Theorem. Calculus of residues. Additional topics may include conformal mappings and the application of complex transforms to differential equations. (Three 50 minute lectures)
Prerequisites: (21-236 Min. grade B or 21-356 Min. grade B or 21-456 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-624 Descriptive Set Theory

Intermittent: 12 units
The central theme of the course is the study of "definable" subsets of Polish spaces (a class of topological spaces containing many spaces studied across mathematics). In some sense, restricting attention to definable sets makes life nicer; for instance, (properly interpreted) the continuum hypothesis becomes true! And weird Banach-Tarski stuff doesn't happen. However, it comes at a price: equivalence relations can have more classes than elements, and acyclic graphs can become hard to properly color. For the first portion of the course we will work through the basic theory of Borel and analytic subsets of Polish spaces, highlighting their interaction with measure and Baire category. We will then focus on the modern theory of equivalence relations, paying special attention to orbit equivalence relations of group actions and connectedness relations of graphs. Along the way we will establish several classical dichotomy theorems. (Three 50 minute lectures)
Prerequisites: (21-355 Min. grade B or 21-455 Min. grade B or 21-235 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B) and 21-329 Min. grade B

21-630 Ordinary Differential Equations

Intermittent: 12 units
Basic concepts covered are existence and uniqueness of solutions, continuation of solutions, continuous dependence, and stability. For autonomous systems, topics included are: orbits, limit sets, Liapunov's direct method, and Poincar-Bendixson theory. For linear systems, topics included are: fundamental solutions, variation of constants, stability, matrix exponential solutions, and saddle points. Time permitting, one or more of the following topics will be covered: differential inequalities, boundary-value problems and Sturm-Liouville theory, Floquet theory. (Three 50 minute lectures)
Prerequisites: (21-355 Min. grade B or 21-235 Min. grade B or 21-455 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

21-632 Introduction to Differential Equations

Fall: 12 units
This course serves as a broad introduction to Ordinary and Partial Differential Equations for beginning graduate students and advanced undergraduate students in mathematics, engineering, and the applied sciences. Mathematical sophistication in real analysis at the level of 21-355/356 is assumed. Topics include: essentials of Ordinary Differential Equations, origins of Partial Differential Equations, the study of model problems including the Poisson and Laplace equations, the heat equation, the transport equation, and the wave equation. (Three 50 minute lectures)
Prerequisites: (21-356 Min. grade B or 21-236 Min. grade B or 21-456 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

21-640 Introduction to Functional Analysis

Spring: 12 units
Linear spaces: Hilbert spaces, Banach spaces, topological vector spaces. Hilbert spaces: geometry, projections, Riesz Representation Theorem, bilinear and quadratic forms, orthonormal sets and Fourier series. Banach spaces: continuity of linear mappings, Hahn-Banach Theorem, uniform boundedness, open-mapping theorem. Closed operators, closed graph theorem. Dual spaces: weak and weak-star topologies (Banach-Alaoglu Theorem), reflexivity. Space of bounded continuous functions and its dual. Linear operators and adjoints: basic properties, null spaces and ranges. Compact operators. Sequences of bounded linear operators: weak, strong and uniform convergence. Introduction to spectral theory: Notions of spectrum and resolvent set of bounded operators, spectral theory of compact operators. Time permitting: Fredholm Alternative. Time permitting: Stone-Weierstrass Theorem. (Three 50 minute lectures)
Prerequisites: (21-236 Min. grade B or 21-651 Min. grade B) and (21-720 Min. grade B or 21-236 Min. grade B)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-651 General Topology

Fall: 12 units
Metric spaces: continuity, compactness, Arzela-Ascoli Theorem, completeness and completion, Baire Category Theorem. General topological spaces: bases and subbases, products, quotients, subspaces, continuity, topologies generated by sets of functions, homeomorphisms. Convergence: nets, filters, and the inadequacy of sequences. Separation: Hausdorff spaces, regular spaces, completely regular spaces, normal spaces, Urysohn's Lemma, Tietze's Extension Theorem. Connectedness. Countability conditions: first and second countability, separability, Lindelof property. Compactness: Tychonoff's Theorem, local compactness, one-point compactification. (Three 50 minute lectures)
Prerequisites: (21-455 Min. grade B or 21-235 Min. grade B or 21-355 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

21-660 Introduction to Numerical Analysis I

Spring: 12 units
Finite precision arithmetic, interpolation, spline approximation, numerical integration, numerical solution of linear and nonlinear systems of equations, optimization in finite dimensional spaces. (Three 50 minute lectures)
Prerequisites: (21-456 Min. grade B or 21-356 Min. grade B or 21-236 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

21-670 Linear Algebra for Data Science

Fall: 6 units
This course is designed to present and discuss those aspects of Linear Algebra that are most important in Data Analytics. The emphasis will be on developing intuition and understanding how to use linear algebra, rather than on proofs. (Three 50 minute lectures)
Prerequisites: (21-455 Min. grade B or 21-355 Min. grade B or 21-235 Min. grade B) and 21-373 Min. grade B

21-671 Computational Linear Algebra

Fall: 12 units
This is a survey of methods in computational linear algebra. Topics covered in this course focus around algorithms for solving (dense or large and sparse) linear systems. Regularization and underdetermined systems will be discussed in detail. Rather than assuming prior knowledge in numerical analysis or matrix theory, we will introduce standard methods or results when needed. In this way, much of the material is self-contained. Theoretical and experimental results will be covered accordingly, with an emphasis on cost, stability, and convergence. (Three 50 minute lectures)
Prerequisites: (21-240 or 21-242 or 21-241) and (21-268 or 21-269 or 21-259)

21-681 Stochastic Calculus in Finance

Intermittent: 6 units
This is a graduate-level introduction to continuous-time equilibrium asset pricing models. Using tools from Ito calculus, the first part of the course covers the benchmark case of complete, frictionless markets, for which a fairly general theory and a number of solvable examples have been developed. The second part of the course then provides an overview of cutting-edge research on extensions of the baseline model that account for "flaws and frictions" such as heterogeneous beliefs, trading costs, or asymmetric information. In the third part of the course, students will present a related research paper, chosen together with the instructor in accordance with their background and research interests. (One 80 minute lecture)
Prerequisites: (21-355 Min. grade B or 21-235 Min. grade B or 21-455 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

21-690 Methods of Optimization

Intermittent: 12 units
An introduction to the theory and algorithms of linear and nonlinear programming with an emphasis on modern computational considerations. The simplex method and its variants, duality theory and sensitivity analysis. Large-scale linear programming. Optimality conditions for unconstrained nonlinear optimization. Newton's method, line searches, trust regions and convergence rates. Constrained problems, feasible-point methods, penalty and barrier methods, interior-point methods. (Three 50 minute lectures)
Prerequisites: (21-356 Min. grade B or 21-236 Min. grade B or 21-456 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

Course Website: https://www.cmu.edu/math/undergrad/math-course-information.html

21-701 Discrete Mathematics

Fall: 12 units
Combinatorial analysis, graph theory with applications to problems in computational complexity, networks, and other areas. (Three 50 minute lectures)
Prerequisites: (21-455 Min. grade B or 21-235 Min. grade B or 21-355 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

21-702 Set Theory II

Spring: 12 units
This course is a sequel to 21-602 Set Theory. The main goal is to prove Solovay's theorem that Con(ZFC + an inaccessible cardinal) implies Con(ZF + DC + every set of reals is Lebesgue measurable). Topics covered include absoluteness theorems, Borel codes, the Levy collapse, product forcing, relative constructibility, and the basics of iterated forcing up to the consistency of Martin's Axiom. (Three 50 minute lectures)
Prerequisites: (21-235 Min. grade B or 21-355 Min. grade B or 21-455 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B) and 21-602 Min. grade B

21-703 Model Theory II

Spring: 12 units
The course concentrates in what is considered "main stream model theory" with is Shelah's classification theory (known also as Stability). Among the topics to be presented are stability, superstability, the theory of various notions of primeness, rank functions, forking calculus, the stability spectrum theorem, finite equivalence relations theorem, stable groups (up to and including the Macintyre-Cherlin-Shelah theorem on super-stable fields), and some elementary geometric model theory. If time permits also: basic facts about infinitary languages, computation of Hanf-Morley numbers; some of the Ax-Kochen-Ershov theory of model theory for fields with valuations (will apply this to solve Artin's conjecture). (Three 50 minute lectures)
Prerequisites: (21-355 Min. grade B or 21-235 Min. grade B or 21-455 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B) and 21-603 Min. grade B

Course Website: http://www.math.cmu.edu/~rami/mt2.11.desc.html

21-720 Measure and Integration

Fall: 12 units
The Lebesgue integral, absolute continuity, signed measures and the Radon-Nikodym Theorem, Lp spaces and the Riesz Representation Theorem, product measures and Fubini's Theorem. (Three 50 minute lectures)
Prerequisites: (21-355 Min. grade B or 21-455 Min. grade B or 21-235 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

21-721 Probability

Spring: 12 units
Probability spaces, random variables, expectation, independence, Borel-Cantelli lemmas. Kernels and product spaces, existence of probability measures on infinite product spaces, Kolmogorov's zero-one law. Weak and strong laws of large numbers, ergodic theorems, stationary sequences. Conditional expectation: characterization, construction and properties. Relation to kernels, conditional distribution, density. Filtration, adapted and predictable processes, martingales, stopping times, upcrossing inequality and martingale convergence theorems, backward martingales, optional stopping, maximal inequalities. Various applications of martingales: branching processes, Polya's urn, generalized Borel-Cantelli, Levy's 0-1 law, martingale method, strong law of large numbers, etc. Weak convergence of probability measures, characteristic functions of random variables, weak convergence in terms of characteristic functions. Central limit theorem, Poisson convergence, Poisson process. Large deviations, rate functions, Cramer's Theorem. (Three 50 minute lectures)
Prerequisites: (21-235 Min. grade B or 21-355 Min. grade B or 21-455 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B) and 21-721 Min. grade B

21-723 Advanced Real Analysis

Spring: 12 units
This course is a sequel to 21-720 Measure and Integration. It is meant to introduce students to a number of important advanced topics in analysis.Topics include: distributions, Fourier series and transform, Sobolev spaces, Bochner integration, basics of interpolation theory, integral transforms. (Three 50 minute lectures)
Prerequisites: (21-356 Min. grade B or 21-236 Min. grade B or 21-456 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B) and 21-720 Min. grade B

21-724 Sobolev Spaces

Intermittent: 12 units
Weak derivatives, Sobolev spaces of integer order, embedding theorems, interpolation inequalities, traces. (Three 50 minute lectures)
Prerequisites: (21-356 Min. grade B or 21-456 Min. grade B or 21-236 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B) and 21-720 Min. grade B

21-732 Partial Differential Equations I

Fall: 12 units
An introduction to the modern theory of partial differential equations. Including functional analytic techniques. Topics vary slightly from year to year, but generally include existence, uniqueness and regularity for linear elliptic boundary value problems and an introduction to the theory of evolution equations. (Three 50 minute lectures)
Prerequisites: 21-723 Min. grade B and 21-632 Min. grade B and 21-640 Min. grade B and (21-237 Min. grade B or 21-373 Min. grade B)

21-737 Probabilistic Combinatorics

Intermittent: 12 units
This course covers the probabilistic method for combinatorics in detail and introduces randomized algorithms and the theory of random graphs. Methods covered include the second moment method, the R and #246;dl nibble, the Lov and #225;sz local lemma, correlation inequalities, martingale's and tight concentration, Janson's inequality, branching processes, coupling and the differential equations method for discrete random processes. Objects studied include the configuration model for random regular graphs, Markov chains, the phase transition in the Erd and #246;s-R and #233;nyi random graph, and the Barab and #225;si-Albert preferential attachment model. (Three 50 minute lectures)
Prerequisites: 21-301 and (21-325 or 15-259 or 36-225 or 36-218)

21-738 Extremal Combinatorics

Intermittent: 12 units
Classical problems and results in extremal combinatorics including the Tur and #225;n and Zarankiewicz problems, the Erdos-Stone theorem and the Erdos-Simonovits stability theorem. Extremal set theory including the Erdos-Rado sunflower lemma and variations, VC-dimension, and Kneser's conjecture. The Szemeredi regularity lemma. Algebraic methods including finite field constructions and eigenvalues and expansion properties of graphs. Shannon capacity of graphs. Chromatic number of Rn and Borsuk's conjecture. Graph decomposition including Graham-Pollack and Baranyai's theorem. (Three 50 minute lectures)
Prerequisites: (21-235 Min. grade B or 21-455 Min. grade B or 21-355 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

21-742 Calculus Of Variations

Intermittent: 12 units
Classical fixed endpoint examples. Fixed endpoint problems in classes of absolutely continuous functions: existence via lower semicontinuity. Tonelli's existence theorem. Euler-Lagrange and DuBois Reymond equations, transversality conditions, Weierstrass field theory, Hamilton-Jacobi theory. Problems with constraints. (Three 50 minute lectures)
Prerequisites: (21-455 Min. grade B or 21-235 Min. grade B or 21-355 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B) and 21-723 Min. grade B

21-752 Algebraic Topology

Intermittent: 12 units
Topology is a less rigid variant of geometry that studies shapes of spaces. Algebraic topology associates algebraic invariants, such as groups or rings, to such spaces. This is achieved by building a space from simpler ones or by algebraically keeping track of how to map a simple space into a given space. This course will cover the fundamental group and covering spaces, homology theories, and the cohomology ring of a space (time permitting). (Three 50 minute lectures)
Prerequisites: 21-651 Min. grade B and (21-455 Min. grade B or 21-355 Min. grade B or 21-235 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

21-759 Differential Geometry

Intermittent: 12 units
Manifolds in Euclidean spaces, curves and surfaces, principal curvatures, geodesics. Surfaces with constant mean curvature, minimal surfaces. Abstract differentiable manifolds, tangent spaces, vector bundles, affine connections, parallelisms, covariant gradients, Cartan torsion, Riemann curvature. Riemannian geometry, Lie groups. Familiarity with analysis in finite dimensional spaces will be assumed. (Three 50 minute lectures)
Prerequisites: (21-236 Min. grade B or 21-356 Min. grade B or 21-456 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

21-762 Finite Element Methods

Intermittent: 12 units
Finite element methods for elliptic boundary value problems. Analysis of errors, approximation by finite element spaces. Efficient implementation of finite element spaces. Efficient implementation of finite element algorithms, finite element methods for parabolic and eigenvalue problems, effects of curved boundaries. Numerical quadrature, non-conforming methods. (Three 50 minute lectures)
Prerequisites: (21-456 Min. grade B or 21-236 Min. grade B or 21-356 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

21-765 Introduction to Parallel Computing and Scientific Computation

Spring: 9 units
Course objectives: to develop structural intuition of how the hardware and the software work, starting from simple systems to complex shared resource architectures; to provide guidelines about how to write and document a software package; to familiarize the audience with the main parallel programming techniques and the common software packages/libraries. (One 110 minute lecture)

Course Website: http://www.math.cmu.edu/~florin/M21-765/index.html (http://www.math.cmu.edu/~florin/M21-765/)

21-770 Introduction to Continuum Mechanics

Intermittent: 12 units
General discussion of the behavior of continuous bodies with an emphasis on those concepts common to the description of all continuous bodies. Specific examples from elasticity and fluid mechanics. Familiarity with analysis in finite dimensional spaces will be assumed. (Three 50 minute lectures)
Prerequisites: (21-456 Min. grade B or 21-236 Min. grade B or 21-356 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

21-800 Advanced Topics in Logic

Intermittent: 12 units
This course affords students with the opportunity to study topics which are in the area of expertise of the instructor. This course may taken more than once if content is sufficiently different. Course prerequisites will depend on the content of the course. Please see the course URL for semester-specific topics. (Three 50 minute lectures)
Prerequisites: (21-355 Min. grade B or 21-455 Min. grade B or 21-235 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

Course Website: https://www.cmu.edu/math/courses/special-topics.html

21-801 Advanced Topics in Discrete Mathematics

Intermittent: 12 units
Course topics will vary depending on the semester and instructor. May be taken more than once if content is sufficiently different. (Three 50 minute lectures)
Prerequisites: (21-355 Min. grade B or 21-235 Min. grade B or 21-455 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

21-803 Model Theory III

Spring: 12 units
We will concentrate in classification theory for first-order theories. The theory was developed mostly by Saharon Shelah presented in his 1978 (2nd ed 1990) book and in several hundreds of papers. We will present a modern overview of Shelah's theory incorporating few recent innovations and simplifications. The development of the theory was motivated by set-theoretic questions like: "what is the asymptotic behavior of the function I(/aleph_/alpha,T) as a function of /alpha ?" and "what is the first /lambda such that an uncountable first-order stable theory T is stable in /lambda?" Surprisingly the full answer to such combinatorial set-theoretic questions led for a development and discovery of a conceptually rich theory which seems to be related to aspects of commutative algebra and algebraic-geometry. This theory found several applications in the form of solving fundamental problems in classical fields of mathematics among them geometry and number theory. The focus will be on the simplest and most fundamental aspects of the pure theory. Primarily around a notion called forking and various characterizations of classes of theories. (Three 50 minute lectures)
Prerequisites: (21-355 Min. grade B or 21-235 Min. grade B or 21-455 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B) and 21-703 Min. grade B

21-820 Advanced Topics in Analysis

Intermittent: 12 units
Course topics will vary depending on the semester and instructor. May be taken more than once if content is sufficiently different.
Prerequisites: (21-456 Min. grade B or 21-236 Min. grade B or 21-356 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

Course Website: https://www.cmu.edu/math/courses/special-topics.html

21-830 Advanced Topics in Partial Differential Equations

Intermittent: 12 units
Course topics will vary depending on the semester and instructor. May be taken more than once if content is sufficiently different.
Prerequisites: (21-355 Min. grade B or 21-455 Min. grade B or 21-235 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B) and 21-632 Min. grade B

21-832 Partial Differential Equations II

Intermittent: 12 units
Elliptic boundary value problems, Green's theorem calculations, integral equation methods, variational formulations and Galerkin's method, regularity theory, parabolic problems and semigroups. (Three 50 minute lectures)
Prerequisites: (21-236 Min. grade B or 21-356 Min. grade B or 21-456 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B) and 21-732 Min. grade B

21-849 Special Topics

Intermittent: 12 units
This course affords students with the opportunity to study topics which are in the area of expertise of the instructor. This course may taken more than once if content is sufficiently different. Course prerequisites will depend on the content of the course. Please see the course URL for semester-specific topics. (Three 50 minute lectures)
Prerequisites: (21-355 Min. grade B or 21-455 Min. grade B or 21-235 Min. grade B) and 21-373 Min. grade B and 21-721 Min. grade B

Course Website: https://www.cmu.edu/math/courses/special-topics.html

21-860 Advanced Topics In Numerical Analysis

Intermittent: 12 units
Content varies. May be taken more than once if content is sufficiently different. (Three 50 minute lectures)
Prerequisites: (21-355 Min. grade B or 21-455 Min. grade B or 21-235 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B) and 21-660 Min. grade B

21-880 Stochastic Calculus

Fall: 12 units
This is a first Ph.D.-level course in stochastic calculus for continuous-time processes. It includes martingales and semi-martingales, Brownian motion, the Poisson process, representation of continuous martingales as time-changed Brownian motions, construction of the Ito integral, and Ito's formula. (Two 80 minute lectures)
Prerequisites: (21-355 Min. grade B or 21-455 Min. grade B or 21-235 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B) and 21-721 Min. grade B

21-882 Advanced Topics in Financial Mathematics

Intermittent: 12 units
Content varies. May be taken more than once if content is sufficiently different. (Two 80 minute lectures)
Prerequisites: (21-235 Min. grade B or 21-355 Min. grade B or 21-455 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B) and 21-721 Min. grade B

21-901 Master's Degree Research

All Semesters
This course is for students admitted to the Mathematical Sciences Honors Degree Program. It allows for students to engage in research activities related to their Master's thesis, under the supervision of their thesis supervisor. The supervisor should be contacted prior to enrollment in 21-901, as they are required to provide consent for the student's enrollment to the Academic Program Coordinator, who authorizes enrollment in this course.

Department of Physics

Rachel Mandelbaum, Interim Department Head
Location: Wean Hall 7325

Gillian Lynn Ryan, Director of Undergraduate Affairs
Location: Wean Hall 7303

Hanann Marawi, Academic Program Manager
Location: Wean Hall 7319
www.cmu.edu/physics (http://www.cmu.edu/physics/)

Physics, one of the basic sciences, has its origin in the irrepressible human curiosity to explore and understand the natural world. This fundamental urge to discover has led to the detailed understanding of a remarkable variety of physical phenomena. Our knowledge now encompasses the large-scale movement of galaxies, the minute motions within atoms and nuclei, and the complex structure of the assemblies of molecules that make life possible. The spectacular expansion of our comprehension of the physical world forms an impressive part of the intellectual and cultural heritage of our times. The opportunity to add to this heritage is an important source of motivation for young physicists. The application of discoveries in physics to the solution of complex modern technological problems offers a vast field in which physicists make decisive contributions. The interplay of pure and applied physics has always been fruitful and today ensures many rewarding career opportunities for physics students. The deep understanding of the physical world developed by physics majors prepares them for success in a wide variety of careers well beyond physics, from medicine to all the sciences and engineering.

Carnegie Mellon's undergraduate curriculum in physics has been carefully designed to provide a firm knowledge of the basic principles of physics, an appreciation of a wide range of physical problems of current interest, and the capacity to formulate and solve new problems. In addition to classwork and problem solving, the curriculum includes studying physical phenomena in the laboratory. Physics students are strongly encouraged to go beyond the formal theoretical and experimental course work and become involved in research projects under the guidance of individual faculty members.

Students may choose from a variety of degree options. The objectives and requirements for each of these options are described below. Each allows considerable latitude in the choice of electives:

Students pursuing a B.S. in Physics, with any track, will take all courses from the Physics, Mathematics, and Technical Core lists, and take an appropriate selection of courses from the Technical, Non-Technical, Physics Breadth, and Qualifying Physics Elective lists. These lists are detailed below.

Through the judicious choice of elective courses, a double major program combining physics and another discipline can be readily achieved. A minor in physics is also offered for those students who major in other disciplines. The student, with the help of their faculty advisors, can easily build a program that aims at specific career objectives.

The Department maintains an active and wide-ranging program of advising. Beyond aiding in academic planning, the Director of Undergraduate Affairs can also assist students in finding research work during the academic year, technical jobs and internships for the summer, as well as planning and executing the necessary steps for gaining employment or continuing their studies beyond the bachelor's degree. Whether students follow a standard curriculum or not, they should consult their academic advisor at least once every semester.

B.S. in Physics

B.S. degree candidates can choose studies in not only a wide variety of intermediate and advanced topics in physics but also a range of material in other science or engineering fields. The B.S. degree provides a solid foundation for students wishing to go on to graduate work in physics or any of a large number of fields in pure or applied science or engineering for which a sound grasp of physics and mathematics is essential. This program also provides excellent preparation for careers in teaching, for work in industrial or governmental research and development, or for other employment in business or industry with a significant scientific component.

Degree Requirements

Physics Core:

All physics majors take these courses in physics, which are designed to teach the fundamentals required for any specialty. Many students take the 100-level courses in their first year of study, the 200-level courses in their second year, and the 300-level courses in their third or fourth year.

		Units
33-121	Physics I for Science Students	12
or 33-151	Matter and Interactions I	
Corequisite for 33-121 is 21-120		
33-142	Physics II for Engineering and Physics Students	12
or 33-152	Matter and Interactions II	
33-104	Experimental Physics	9
33-201	Physics Sophomore Colloquium I	2
33-211	Physics III: Modern Essentials	10
33-231	Physical Analysis	10
33-202	Physics Sophomore Colloquium II	2
33-228	Electronics I	10
33-232	Mathematical Methods of Physics	10
33-234	Quantum Physics	10
33-301	Physics Upperclass Colloquium I	1
33-331	Physical Mechanics I	10
33-338	Intermediate Electricity and Magnetism I	10
33-341	Thermal Physics I	10
33-302	Physics Upperclass Colloquium II	1
33-340	Modern Physics Laboratory	10
Total Physics Core Units		**129**

Mathematics Core:

All physics majors take these calculus courses from the Department of Mathematics to support their studies in physics.

		Units
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-259	Calculus in Three Dimensions	10
Total Mathematics Core Units		**30**

Technical Core:

All students in the Mellon College of Science take courses in the Life Sciences, Physical Sciences, and Mathematics, Statistics, or Computer Science to gain the technical breadth necessary for interdisciplinary work. The following three courses have been selected specifically for physics majors to give them the technical breadth they need.

		Units
03-121	Modern Biology [1]	9
09-105	Introduction to Modern Chemistry I [2]	10
15-110	Principles of Computing [3]	10-12
or 15-112	Fundamentals of Programming and Computer Science	
Total Technical Core Units		**29-31**

[1] If 03-121 is satisfied through placement credit, students should refer to the Mellon College of Science's Life Sciences list to fulfill technical breadth requirement A.

[2] If 09-105 is satisfied through placement credit, students should refer to the Mellon College of Science's Physical Sciences list to fulfill technical breadth requirement B.

[3] If 15-112 is satisfied through placement credit, students should refer to the Mellon College of Science's STEM Course list to fulfill technical breadth requirement D.

Technical Electives:

Physics majors can choose to increase the breadth or depth of their studies through their choices of Technical Electives. Students may choose these electives individually or may take a pre-set selection of technical electives known as a "track" to focus on a specific subfield of physics. **The six available tracks are detailed here.**

		Units
33-xxx	Physics Breadth Elective	9-12
33-xxx	Three Qualifying Physics Electives	27-36
21-2xx	Mathematics Elective	9-10
xx-xxx	Three STEM Electives [4]	27-36
Total Technical Electives Units		**72-94**

[4] STEM electives are any courses in MCS (including Physics), SCS, Statistics, CIT, and others explicitly approved by the Director of Undergraduate Affairs.

Non-Technical Electives:

The Mellon College of Science requires that all students take a variety of non-technical courses to strengthen their understanding of both themselves and the world at large.

		Units
99-101	Core@CMU	3
76-101	Interpretation and Argument	9
38-101	EUREKA!: Discovery and Its Impact	6
38-110	ENGAGE in Service	1
38-220	ENGAGE in the Arts	2
38-230	ENGAGE in Wellness: Looking Inward	1
38-330	ENGAGE in Wellness: Looking Outward	1
38-430	ENGAGE in Wellness: Looking Forward	1
38-304	Reading and Writing Science [5]	6
xx-xxx	Cultural/Global Understanding Elective [6]	9
xx-xxx	Four Non-Technical Electives [7]	36
Total Non-Technical Units		**75**

[5] Refer to the Mellon College of Science's Science and Society list for alternate courses that will fulfill this requirement. Placement credit may not be used.

[6] Refer to the Mellon College of Science's Cultural/Global Understanding list for courses that will fulfill this requirement. Placement credit may not be used.

[7] Refer to the Mellon College of Science's Arts, Humanities, and Social Sciences section for courses that will fulfill the non-technical electives requirement. Up to 18 units may be fulfilled through placement credit.

Free Electives:

All students must complete a minimum of 360 units to earn a bachelor's degree in the Mellon College of Science. Students are welcome to take more than the minimum 360 units required.

		Units
xx-xxx	Free Electives [8]	1-26
Total Free Elective Units		**1-26**

[8] A maximum of 9 units of physical education and/or military science and/or STUCO courses may be taken as free electives.

Sample Schedule (No Track)

BEGINNING FALL 2015 AND BEYOND

First Year

Fall		Units
99-101	Core@CMU	3
38-101	EUREKA!: Discovery and Its Impact	6
33-121	Physics I for Science Students	12
or 33-151	Matter and Interactions I	
Corequisite for 33-121 is 21-120 & for 33-151 is 21-122		
21-120	Differential and Integral Calculus	10
or 21-122	Integration and Approximation	
xx-xxx	MCS/Physics Technical Core Requirement 1 of 3	9-12
76-101	Interpretation and Argument	9
or 76-100	Reading and Writing in an Academic Context	
First-Year Fall Units		**49-52**

Spring		Units
33-142	Physics II for Engineering and Physics Students	12
or 33-152	Matter and Interactions II	
Corequisite for 33-142 is 21-122 & for 33-152 is 21-259		
33-104	Experimental Physics	9
21-122	Integration and Approximation	10
or 21-259	Calculus in Three Dimensions	
xx-xxx	MCS/Physics Technical Core Requirement 2 of 3	9-12
xx-xxx	Non-Technical Elective 1 of 4	9
First-Year Spring Units		**49-52**

Sophomore Year

Fall		Units
33-201	Physics Sophomore Colloquium I	2
33-211	Physics III: Modern Essentials	10
33-231	Physical Analysis	10
21-259	Calculus in Three Dimensions (if not already taken)	10
xx-xxx	MCS/Physics Technical Core Requirement 3 of 3	9-12
xx-xxx	Cultural/Global Understanding Elective	9-12
Sophomore Fall Units		**50-56**

Spring		Units
38-230	ENGAGE in Wellness: Looking Inward	1
33-202	Physics Sophomore Colloquium II	2
33-228	Electronics I	10
33-232	Mathematical Methods of Physics	10
33-234	Quantum Physics	10
xx-xxx	Technical Elective 1 of 8	9-12
Sophomore Spring Units		**42-45**

Junior Year

Fall		Units
38-330	ENGAGE in Wellness: Looking Outward	1
33-301	Physics Upperclass Colloquium I	1
33-331	Physical Mechanics I	10
33-338	Intermediate Electricity and Magnetism I	10
33-341	Thermal Physics I	10
xx-xxx	Technical Elective 2 of 8	9-12
Junior Fall Units		**41-44**

Spring		Units
33-302	Physics Upperclass Colloquium II	1

38-304	Reading and Writing Science (Science and Society)	6
33-340	Modern Physics Laboratory	10
38-110	ENGAGE in Service	1
xx-xxx	Technical Elective 3 of 8	9-12
xx-xxx	Technical Elective 4 of 8	9-12
xx-xxx	Non-Technical Elective 2 of 4	9-12
Junior Spring Units		**45-54**

Senior Year

Fall		Units
38-430	ENGAGE in Wellness: Looking Forward	1
38-220	ENGAGE in the Arts	2
xx-xxx	Technical Elective 5 of 8	9-12
xx-xxx	Technical Elective 6 of 8	9-12
xx-xxx	Non-Technical Elective 3 of 4	9-12
xx-xxx	Free Elective	9-12
xx-xxx	Free Elective	9-12
Senior Fall Units		**48-63**

Spring		Units
xx-xxx	Technical Elective 7 of 8	9-12
xx-xxx	Technical Elective 8 of 8	9-12
xx-xxx	Non-Technical Elective 4 of 4	9-12
xx-xxx	Free Elective	9-12
Senior Spring Units		**36-48**

B.A. in Physics

The Bachelor of Arts degree in Physics offers a flexible program that allows students to combine the study of Physics with the opportunity to do intensive work in substantive areas such as liberal arts, teaching, business or law. With up to 80 units of free electives, it is feasible for students to obtain, for example, an additional major with a department in the Dietrich College of Humanities and Social Sciences, the College of Fine Arts, or the Tepper School of Business. It is expected that students will focus their elective courses in a well-defined academic area. Students must meet with the Director of Undergraduate Affairs and construct an approved plan of study.

The requirements for the B.A. degree are the same as for the B.S. degree, except that 6 of the Physics, Mathematics and Technical Electives in the B.S. program become Free Electives in the BA program. These requirements are listed below.

Degree Requirements

Physics Core:

All physics majors take these courses in physics, which are designed to teach the fundamentals required for any specialty. Many students take the 100-level courses in their first year of study, the 200-level courses in their second year, and the 300-level courses in their third or fourth year.

		Units
33-121	Physics I for Science Students	12
or 33-151	Matter and Interactions I	
Corequisite for 33-121 is 21-120		
33-142	Physics II for Engineering and Physics Students	12
or 33-152	Matter and Interactions II	
Corequisite for 33-142 is 21-122		
33-104	Experimental Physics	9
33-201	Physics Sophomore Colloquium I	2
33-211	Physics III: Modern Essentials	10
33-231	Physical Analysis	10
33-202	Physics Sophomore Colloquium II	2
33-228	Electronics I	10
33-232	Mathematical Methods of Physics	10
33-234	Quantum Physics	10
33-301	Physics Upperclass Colloquium I	1
33-331	Physical Mechanics I	10
33-338	Intermediate Electricity and Magnetism I	10
33-341	Thermal Physics I	10
33-302	Physics Upperclass Colloquium II	1
33-340	Modern Physics Laboratory	10
Total Physics Core Units		**129**

Mathematics Core:

All Physics Majors take these courses from the Department of Mathematics to support their studies in Physics.

		Units
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-259	Calculus in Three Dimensions	10
Total Mathematics Core Units		**30**

Technical Core:

All students in the Mellon College of Science take courses in the Life Sciences, Physical Sciences, and Mathematics, Statistics, or Computer Science to gain the technical breadth necessary for interdisciplinary work. These three courses have been selected specifically for Physics Majors to give them the technical breadth they need

		Units
03-121	Modern Biology [9]	9
09-105	Introduction to Modern Chemistry I [10]	10
15-112	Fundamentals of Programming and Computer Science [11]	10-12
or 15-110	Principles of Computing	
Total Technical Core Units		**29-31**

[9] If 03-121 is satisfied through placement credit, students should refer to the Mellon College of Science's Life Sciences list to fulfill technical breadth requirement A.

[10] If 09-105 is satisfied through placement credit, students should refer to the Mellon College of Science's Physical Sciences list to fulfill technical breadth requirement B.

[11] If 15-112 is satisfied through placement credit, students should refer to the Mellon College of Science's STEM Course list to fulfill technical breadth requirement D.

Technical Electives:

While students pursuing a B.S. in Physics are required to take a minimum of 8 Physics, Mathematics, and STEM electives, students pursuing a B.A. in Physics need only take a minimum of 2 Qualifying Physics Electives.

		Units
33-xxx	Two Qualifying Physics Electives	18-24
Total Technical Electives		**18-24**

Non-Technical Electives:

The Mellon College of Science requires that all students take a variety of non-technical courses to strengthen their understanding of both themselves and the world at large. The precise requirements are different for those entering before and after the Fall of 2015.

		Units
99-101	Core@CMU	3
76-101	Interpretation and Argument	9
38-101	EUREKA!: Discovery and Its Impact	6
38-110	ENGAGE in Service	1
38-220	ENGAGE in the Arts	2
38-230	ENGAGE in Wellness: Looking Inward	1
38-330	ENGAGE in Wellness: Looking Outward	1
38-304	Reading and Writing Science [12]	6
38-430	ENGAGE in Wellness: Looking Forward	1
xx-xxx	Cultural/Global Understanding Elective [13]	9
xx-xxx	Four Non-Technical Electives [14]	36
Total Non-Technical Elective Units		**75**

[12] Refer to the Mellon College of Science's Science and Society list for alternate courses that will fulfill this requirement. Placement credit may not be used.

[13] Refer to the Mellon College of Science's Cultural/Global Understanding list for courses that will fulfill this requirement. Placement credit may not be used.

[14] Refer to the Mellon College of Science's Arts, Humanities, and Social Sciences section for courses that will fulfill the non-technical electives requirement. Up to 18 units may be fulfilled through placement credit.

Free Electives:

All students must complete a minimum of 360 units to earn a bachelor's degree in the Mellon College of Science. Students are welcome to take more than the minimum 360 units required. The B.A. in Physics replaces 6 Technical Electives with Free Electives, compared to the B.S. in Physics.

		Units
xx-xxx	Free Electives [15]	72-80
Total Free Electives		**72-80**

[15] A maximum of 9 units of physical education and/or military science and/or StuCo courses may be taken as free electives.

Physics Electives

Physics Breadth Electives

Students pursuing a B.S. in Physics must take at least one course from the Physics Breadth Elective list to gain experience in a subfield of physics. Some tracks have this course prescribed, while others allow free choice from this list. All of these courses may also be taken as Qualifying Physics Electives, but they may not fulfill both requirements simultaneously.

		Units
33-224	Stars, Galaxies and the Universe	9
33-226	Physics of Energy	9
33-353	Intermediate Optics	12
33-355	Nanoscience and Nanotechnology	9
33-441	Introduction to Biophysics	10
33-444	Introduction to Nuclear and Particle Physics	9
33-448	Introduction to Solid State Physics	9
33-466	Extragalactic Astrophysics and Cosmology	9
33-467	Astrophysics of Stars and the Galaxy	9
33-650	General Relativity	9

Total Physics Breadth Elective Units 9-12

Qualifying Physics Electives

Students pursuing a B.S. in Physics must take at least three courses totaling at least 27 units from the Qualifying Physics Elective list, not including the 100-level courses. Some tracks have these courses prescribed, while others allow free choice from this list, enabling students to choose between broad and in-depth study. Students pursuing a B.A. in Physics must take at least two courses totaling at least 18 units from this list. Students pursuing a Minor in Physics must take at least three courses totaling at least 27 units from this list or non-prescribed courses from the Physics Core list. While all courses on the Physics Breadth Elective list are also on the Qualifying Physics Elective list, a course may not fulfill both requirements simultaneously. Certain courses are offered only in alternate years, as indicated.

33-114	Physics of Musical Sound (B.A. and Minor only) [16]	9
33-115	Physics for Future Presidents (B.A. and Minor only) [16]	9
33-120	Science and Science Fiction (B.A. and Minor only) [16]	9
33-224	Stars, Galaxies and the Universe	9
33-226	Physics of Energy	9
33-241	Introduction to Computational Physics	9
33-332	Physical Mechanics II	10
33-339	Intermediate Electricity and Magnetism II	10
33-342	Thermal Physics II	10
33-350	Undergraduate Research [17]	Var.
33-353	Intermediate Optics (Alt. Fall - F22, F24)	12
33-355	Nanoscience and Nanotechnology (Alt. Fall - F23, F25)	9
33-441	Introduction to Biophysics	10
33-444	Introduction to Nuclear and Particle Physics	9
33-445	Advanced Quantum Physics I	9
33-446	Advanced Quantum Physics II	9
33-448	Introduction to Solid State Physics	9
33-451	Senior Research [17]	Var.
33-456	Advanced Computational Physics	9
33-466	Extragalactic Astrophysics and Cosmology	9
33-467	Astrophysics of Stars and the Galaxy	9
33-499	Supervised Reading [17]	Var.
33-650	General Relativity	9
33-658	Quantum Computation and Quantum Information Theory	10
33-659	Quantum Hall Effect and Topological Insulators	12
33-7xx	Physics Graduate Level Courses (see list below)	

Total Qualifying Physics Electives Units 27-37

[16] Only one of these three courses (33-114, 33-115, and 33-120) may be used for the B.A. These classes may not be used as Qualifying Physics Electives for the B.S.

[17] Only one of these three courses (33-350, 33-451, and 33-499) of 9 units may be used as a Qualifying Physics Elective. Any exceptions must be approved by the Director of Undergraduate Affairs.

Qualifying Physics Electives Recommended for Physics Graduate School

Students planning to undertake graduate studies in physics are strongly advised to take the following courses, which may count as Qualifying Physics Electives and STEM Electives.

		Units
33-332	Physical Mechanics II	10
33-339	Intermediate Electricity and Magnetism II	10
33-445	Advanced Quantum Physics I	9
33-446	Advanced Quantum Physics II	9

Qualifying Physics Electives Recommended for Graduate School in Physics

Physics Graduate Courses

These courses are intended for graduate students in physics, but may be taken by advanced undergraduates as Qualifying Physics or STEM Electives. **Undergraduate students require special permission of the instructor and the Director of Undergraduate Affairs to register for these classes.**

		Units
33-755	Quantum Mechanics I	12
33-756	Quantum Mechanics II	12
33-758	Quantum Computation and Quantum Information Theory	12
33-759	Introduction to Mathematical Physics I	12
33-761	Classical Electrodynamics I	12
33-762	Classical Electrodynamics II	12
33-765	Statistical Mechanics	12
33-767	Biophysics: From Basic Concepts to Current Research	12
33-769	Quantum Mechanics III: Many Body and Relativistic Systems	12
33-770	Field Theory I	12
33-771	Field Theory II	12
33-777	Introductory Astrophysics	12
33-778	Introduction to Cosmology	12
33-779	Introduction to Nuclear and Particle Physics	12
33-780	Nuclear and Particle Physics II	12
33-783	Solid State Physics	12

Physics Graduate Course Units Optional

Tracks for B.S. in Physics

Students seeking a B.S. in Physics may choose from 5 different Physics tracks, or opt to pursue no track. Each of these tracks fulfills the Technical Electives of the B.S. in Physics. The available tracks are:

- No Track (p. 646)
- Applied Physics (p. 646)

- Astrophysics (p. 646)
- Biological Physics (p. 646)
- Chemical Physics (p. 647)
- Computational Physics (p. 647)
- Quantum Physics (p. 647)

The track descriptions and requirements are listed below.

No Track

Physics students wanting maximum freedom can opt not to select a track. The required Technical Electives are those described in the B.S. in Physics section above, and are reprinted below.

		Units
33-xxx	Physics Breadth Elective	9-12
33-xxx	Three Qualifying Physics Electives	27-37
21-2xx	Mathematics Elective	9-10
xx-xxx	Three STEM Electives [18]	27-36
Total Technical Elective Units		**72-95**

[18] STEM electives are any courses in MCS (including Physics), SCS, Statistics, CIT, and others explicitly approved by the Director of Undergraduate Affairs.

Applied Physics Track

The B.S. in Physics/Applied Physics Track is designed primarily for students who want to prepare for a career path that takes advantage of the diverse and expanding opportunities for employment in industrial and government laboratories with a B.S. degree. The program provides a solid foundation in the concepts of physics, as well as giving the student the experience and understanding of the application of these concepts. The track is intended to enhance computing and laboratory skills, and to introduce the application of physics to those subjects of particular interest to the student. Since the possible subject areas for study are so varied, the track will be tailored to each student's needs within the framework described below.

		Units
33-448	Introduction to Solid State Physics	9
xx-xxx	Computational Science Course [19]	9-12
xx-xxx	Four Applied Physics/Laboratory Electives [19]	36-48
33-350	Undergraduate Research [19]	9
or 33-451	Senior Research	
21-2xx	Mathematics Elective	9-10
Total Applied Track Elective Units		**72-88**

[19] The elective courses and research topic are decided after consultation with, and approval by, the Director of Undergraduate Affairs. Research must be completed in a single 9-unit block.

Astrophysics Track

The B.S. in Physics/Astrophysics Track provides an option for those Physics majors who either want to specialize in this subfield or plan careers in astronomy or astrophysics. Career paths may include postgraduate training in astronomy or astrophysics or proceeding directly to jobs in these fields. The program provides a thorough foundation in the core physics program with electives concentrating in astrophysics.

		Units
33-224	Stars, Galaxies and the Universe	9
33-466	Extragalactic Astrophysics and Cosmology	9
33-467	Astrophysics of Stars and the Galaxy	9
33-350	Undergraduate Research [20]	9
or 33-451	Senior Research	
21-2xx	Mathematics Elective	9-10
xx-xxx	Three STEM Electives	27-36
Total Astrophysics Track Elective Units		**72-82**

[20] The research topic must be approved by the Director of Undergraduate Affairs and must be completed in a single 9-unit block.

Biological Physics Track

The B.S. in Physics/Biological Physics Track combines a rigorous foundation in undergraduate physics with courses in Biological Physics and Chemistry. It is particularly suitable for students preparing for post-baccalaureate careers in the expanding areas of biological and medical physics or for graduate study in biophysics. The program is sufficiently flexible that it can be readily adapted to the requirements of individual students. The student will first meet with the Director of Undergraduate Affairs to discuss interests and career goals and then choose electives that fulfill the requirements of the track.

The Biological Physics Track is excellent preparation for Medical School. All courses suggested for medical school applicants can be completed within this track. Students interested in both the Biological Physics Track and the pre-medical program should consult with both the Director of Undergraduate Affairs in the Physics Department and the Director of the Health Professions Program for help in planning their programs.

Program optimized for Biological Physical studies:

		Units
33-441	Introduction to Biophysics	10
or 03-439	Introduction to Biophysics	
33-xxx	One Qualifying Physics Elective	9-12
21-2xx	Mathematics Elective	9-10
03-231	Honors Biochemistry	9
09-217	Organic Chemistry I	9
09-218	Organic Chemistry II	9
03-xxx	Two Biological Sciences Electives [21]	18
Total Biological Physics Track Elective Units		**73-77**

[21] The elective courses in Biological Sciences are decided after consultation with, and approval by, the Director of Undergraduate Affairs.

Program optimized for Medical School preparation:

		Units
03-121	Modern Biology	9
or 03-151	Honors Modern Biology	
42-202	Physiology	9
03-124	Modern Biology Laboratory	9
or 03-206	Biomedical Engineering Laboratory	
or 03-343	Experimental Techniques in Molecular Biology	
09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
09-106	Modern Chemistry II	10
or 09-221	Laboratory I: Introduction to Chemical Analysis	
09-207	Techniques in Quantitative Analysis	9
or 09-221	Laboratory I: Introduction to Chemical Analysis	
09-217	Organic Chemistry I	9
or 09-219	Modern Organic Chemistry	
09-218	Organic Chemistry II	9
or 09-220	Modern Organic Chemistry II	
09-208	Techniques for Organic Synthesis and Analysis	9
or 09-222	Laboratory II: Organic Synthesis and Analysis	
33-121	Physics I for Science Students	12
or 33-141	Physics I for Engineering Students	
Corequisite for 33-121 is 21-120		
33-122	Physics II for Biological Sciences & Chemistry Students	9
or 33-142	Physics II for Engineering and Physics Students	
Corequisite for 33-122 is 21-122		
33-104	Experimental Physics	9
03-231	Honors Biochemistry	9
or 03-232	Biochemistry I	
21-111	Calculus I	10
or 21-120	Differential and Integral Calculus	
21-112	Calculus II (A semester of statistics may substitute for a semester of calculus at many medical schools.) [14]	10
or 21-122	Integration and Approximation	
or 21-124	Calculus II for Biologists and Chemists	
36-200	Reasoning with Data	9
or 36-202	Methods for Statistics & Data Science	
or		
76-101	Interpretation and Argument	9
76-xxx	English II Elective	9

85-xxx	Psychology Elective (Intro to Psychology, Social Psychology)	9
xx-xxx	Intro to Sociology (not offered at CMU)	9
Total Biological Physics Track Elective Units		**187**

Chemical Physics Track

The B.S. in Physics/Chemical Physics Track is designed for students wishing to have a strong grounding in physics along with a specialization in physical chemistry and/or chemical physics. It is particularly suitable for those students planning on graduate studies in physics with an emphasis on chemical physics or chemistry. The program is sufficiently flexible that it can be readily adapted to the requirements of individual students. The student will first meet with the Director of Undergraduate Affairs to discuss interests and career goals and then choose electives that fulfill the requirements of the track.

		Units
33-xxx	One Physics Breadth Elective	9-12
21-2xx	Mathematics Elective	9-10
09-106	Modern Chemistry II	10
09-344	Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry	9
09-345	Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry	9
09-xxx	Three Chemistry Electives [22]	27
Total Chemical Physics Track Elective Units		**73-77**

[22] The elective courses in Chemistry are decided after consultation with, and approval by, the Director of Undergraduate Affairs.

Computational Physics Track

The B.S. in Physics/Computational Physics Track is intended to fill the increasing demand for physics graduates who are skilled in computational and numerical techniques that are used in the analysis of physical problems in areas ranging from academia to Silicon Valley. The degree provides the student with a rigorous grounding in physics as well as in the foundations and practice of computational skills to address theoretical and applied problems in society. Flexibility in the degree requirements allows students to choose technical electives that prepare them for future careers in a range of emerging computational science fields including data science, artificial intelligence, and software development. Students who complete this track will also gain experience in the application of high-performance computing resources to a wide variety of problems.

		Units
33-241	Introduction to Computational Physics	9
33-456	Advanced Computational Physics	9
33-xxx	One Physics Breadth Elective	9-12
33-xxx	One Qualifying Physics Elective or xx-xxx Computational Science Elective [23]	9-12
21-127	Concepts of Mathematics	12
21-369	Numerical Methods	9-12
or 21-325	Probability	
or 36-225	Introduction to Probability Theory	
15-122	Principles of Imperative Computation	12
15-150	Principles of Functional Programming	12
Total Computational Physics Track Elective Units		**81-90**

[23] Selected in consultation with, and requires approval of, the Director of Undergraduate Affairs. Common choices outside qualifying physics electives include 10-301, 11-485, and 15-388, but other options may be approved.

Quantum Physics Track

In the early 20th century, the first quantum revolution led to a disruption of accepted physics paradigms and resulted in rapid innovation in science and technology. The development of the transistor, the laser, and the atomic clock, for example, allowed for innovations in computing, communications, and medical imaging that we now take for granted. The second quantum revolution, defined by the development and application of quantum materials and quantum computing, is poised to unleash another era of innovation in science and technology. The B.S. in Physics/Quantum Physics Track is designed for students who want to prepare for a career at the cutting-edge of this exciting field.

		Units
33-445	Advanced Quantum Physics I	9
33-446	Advanced Quantum Physics II	9
33-658	Quantum Computation and Quantum Information Theory	10
33-448	Introduction to Solid State Physics	9
or 33-444	Introduction to Nuclear and Particle Physics	
or 33-355	Nanoscience and Nanotechnology	
33-350	Undergraduate Research [24]	9
or 33-451	Senior Research	
21-2xx	Mathematics Elective	9-10
xx-xxx	Two STEM Electives	18-24
Total Quantum Track Elective Units		**73-80**

[24] The elective courses and research topic are decided after consultation with, and approval by, the Director of Undergraduate Affairs. Research must be completed in a single 9-unit block.

Additional Major or Dual Degree in Physics

Physics may be taken as an additional major (also known as a "double major") or as a second degree, with another department granting the primary degree. The rules of the Physics Department for these two options are distinct, as discussed below. Students interested in either option should contact Dr. Gillian Ryan, Director of Undergraduate Affairs, for assistance, and should have successfully completed at least one core physics course at Carnegie Mellon prior to applying for these options.

Additional Major

In order to receive an Additional Major in Physics, with another department granting the primary degree — with a B.S. or B.A., alone or with any track — all requirements of the Physics degree and the particular physics track, as listed in the previous sections, must be fulfilled except:

- No STEM Electives are required
- No Non-Technical Electives are required
- 03-121 Modern Biology is not required
- 09-105 Introduction to Modern Chemistry I is not required
- No Free Electives are required

The full requirements are described below.

Physics Core:

All physics majors take these courses in physics, which are designed to teach the fundamentals required for any specialty. Many students take the 100-level courses in their first year of study, the 200-level courses in their second year, and the 300-level courses in their third or fourth year.

		Units
33-121	Physics I for Science Students	12
or 33-151	Matter and Interactions I	
Corequisite for 33-121 is 21-120		
33-142	Physics II for Engineering and Physics Students	12
or 33-152	Matter and Interactions II	
33-104	Experimental Physics	9
33-201	Physics Sophomore Colloquium I	2
33-211	Physics III: Modern Essentials	10
33-231	Physical Analysis	10
33-202	Physics Sophomore Colloquium II	2
33-228	Electronics I	10
33-232	Mathematical Methods of Physics	10
33-234	Quantum Physics	10
33-301	Physics Upperclass Colloquium I	1
33-331	Physical Mechanics I	10
33-338	Intermediate Electricity and Magnetism I	10
33-341	Thermal Physics I	10
33-302	Physics Upperclass Colloquium II	1
33-340	Modern Physics Laboratory	10
Total Physics Core Units		**129**

Mathematics Core:

All physics majors take these calculus courses from the Department of Mathematics to support their studies in physics.

		Units
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-259	Calculus in Three Dimensions	10
Total Mathematics Core Units		**30**

Technical Core for an Additional Major:

Students pursuing an additional major in physics do not need to fulfill the full Technical Core required by the Mellon College of Science, but are still required to take either 15-110 or 15-112 (or an equivalent course as pre-approved by the Associate Dean of Undergraduate Affairs, Mellon College of Science).

		Units
15-110	Principles of Computing	10-12
or 15-112	Fundamentals of Programming and Computer Science	
Total Technical Core Units		**10-12**

Technical Electives for an Additional Major:

Students pursuing an additional major in physics must take the Physics Electives and Mathematics Elective required of physics as the primary major, but do not need to take the STEM electives. Students may choose these electives individually, but may opt to complete the requirements as part of the Physics Tracks (p. 645) described in the B.S. in Physics section. Students interested in completing an additional major with a track should consult with the Director of Undergraduate Affairs.

		Units
33-xxx	Physics Breadth Elective	9-12
33-xxx	3 Qualifying Physics Electives	27-37
21-2xx	Mathematics Elective	9-10
Total Technical Electives		**45-59**

Dual Degree

In order to receive a Dual Degree in another subject and Physics, all requirements of the Physics degree must be fulfilled. Students may choose to complete the B.A. or the B.S. in Physics, with or without a track. Students must complete both the technical and non-technical requirements, and should consult with the Director of Undergraduate Affairs for questions about double counting. The number of units required is 90 more than the total units required by the department requiring the fewer total units. Since Physics requires 360 units, the lowest possible minimum for a Dual Degree with Physics is 450 units.

Minor in Physics

The Minor in Physics is designed to provide a solid foundation in physics at the introductory level, followed by elective courses which will familiarize the student with areas of modern physics, and the concepts and techniques employed therein. The physics minor requires seven courses of at least 9 units each, of which four are required and three are electives.

The Minor is open to all students in the university, but students with non-calculus-based majors should be aware of the mathematics requirements for many physics courses (21-120, 21-122, and 21-259). Students are required to have successfully completed at least one physics course at Carnegie Mellon before declaring the minor, and should declare the minor no later than the add date of their final semester. Interested students should contact Dr. Gillian Ryan, Director of Undergraduate Affairs, and complete the minor declaration form (https://www.cmu.edu/mcs/undergrad/advising/forms/mcs_additional_major-minor.pdf) with her assistance.

		Units
33-121	Physics I for Science Students	12
or 33-141	Physics I for Engineering Students	
or 33-151	Matter and Interactions I	
Corequisite for 33-121 or 33-141 is 21-120 & for 33-151 is 21-122		
33-122	Physics II for Biological Sciences & Chemistry Students	12
or 33-142	Physics II for Engineering and Physics Students	
or 33-152	Matter and Interactions II	
Corequisite for 33-122 or 33-142 is 21-122 & for 33-152 is 21-259		
33-104	Experimental Physics	9
33-211	Physics III: Modern Essentials	10
33-xxx	Three Qualifying Physics Electives or Physics Core Electives [25]	27-36
Total Physics Minor Units		**70-79**

[25] The physics electives are decided after consultation with, and approval by, the Director of Undergraduate Affairs. Students may take courses from the Qualifying Physics List or additional courses from the Physics Core list, such as Quantum Physics or Electronics I.

Transfer Credit Requests

Requests for transfer credit for undergraduate physics classes should be made through the student's home college to the Director of Undergraduate Affairs. Students should contact their departmental academic advisor for the transfer request process in their college. Requests should **not** be made from students directly to the Department of Physics. It is recommended that requests be placed before paying tuition for a class in case transfer credit is denied. Requests may take 1-2 weeks to be processed by the Department of Physics.

Criteria for Transfer

In assessing the suitability of courses for transfer credit, the Department of Physics will consider the following factors:

- The academic rigor of the course must be comparable to that offered at Carnegie Mellon University. This is usually assessed via the course prerequisites and corequisites, the textbook used, and the amount of time spent on topic areas. Completely online classes without in-person proctored examinations do not meet our standard for transfer credit.
- The mathematical rigor of a course must also be comparable to that for the CMU course for which a transfer is requested. For example, a class that has no math prerequisite is unlikely to transfer as a CMU class for which there is such a prerequisite, and algebra-based Physics I or Physics II classes will not be accepted for transfer as our calculus-based courses.
- The topic areas of a given class and time devoted to each topic should match to a degree of at least 80% those covered in the comparable physics course at Carnegie Mellon University, although this criterion alone is not sufficient to merit transfer. Classes that meet this criterion may still be denied transfer credit if key topics are found to be excluded or if the above mentioned requirements regarding rigor are not met.

Requirements for Transfer Requests

The Department of Physics requires all the following materials to determine if transfer is recommended:

- Name of course and its home institution
- Number of credits/units/contact hours per week
- Course syllabus
- Official catalog course description and list of topics covered in the course
- A list of all prerequisite and corequisite courses, and official catalog course descriptions of these courses
- Required textbook (name, author, and link to information about the text required)

Transfer requests that do not include all information above will not be recommended.

Faculty

JOHN ALISON, Associate Professor of Physics – Ph.D., University of Pennsylvania; Carnegie Mellon, 2018–

DAVID ANDERSON, Associate Teaching Professor of Physics – Ph.D., University of York (UK) ; Carnegie Mellon, 2008–

SHILADITYA BANERJEE, Associate Professor of Physics – Ph.D., Syracuse University; Carnegie Mellon, 2020–

KATELYN BREIVIK, Assistant Professor of Physics – Ph.D., Northwestern University; Carnegie Mellon, 2023–

ROY A. BRIERE, Professor of Physics – Ph.D., University of Chicago; Carnegie Mellon, 1999–

SHUBHAYU CHATTERJEE, Assistant Professor of Physics – Ph.D., Harvard University; Carnegie Mellon, 2023–

HAEL COLLINS, Assistant Teaching Professor of Physics – Ph.D., Harvard University; Carnegie Mellon, 2019–

MATTEO CREMONESI, Assistant Professor of Physics – Ph.D., Oxford University; Carnegie Mellon, 2022–

RUPERT CROFT, Professor of Physics – Ph.D., Oxford University; Carnegie Mellon, 2001–

MARKUS DESERNO, Professor of Physics; Director of Graduate Studies, Department of Physics – Ph.D., University of Mainz, Germany; Carnegie Mellon, 2007–

TIZIANA DI MATTEO, Professor of Physics – Ph.D., University of Cambridge; Carnegie Mellon, 2005–

VALENTINA DUTTA, Assistant Professor of Physics – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2022–

SCOTT DODELSON, Professor of Physics – Ph.D., Columbia University; Carnegie Mellon, 2017–

RANDALL M. FEENSTRA, Professor of Physics – Ph.D., California Institute of Technology; Carnegie Mellon, 1995–

FRANK HEINRICH, Associate Research Professor of Physics – Ph.D., University of Leipzig; Carnegie Mellon, 2008–

BENJAMIN HUNT, Associate Professor of Physics – Ph.D., Cornell University; Carnegie Mellon, 2015–

TINA KAHNIASHVILI, Research Professor of Physics – Ph.D., Russian Academy of Sciences; Carnegie Mellon, 2010–

JYOTI KATOCH, Associate Professor or Physics – Ph.D., University of Central Florida; Carnegie Mellon, 2018–

VLADYSLAV KOZII, Assistant Professor of Physics – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2022–

BARRY B. LUOKKALA, Teaching Professor of Physics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1988–

SARA A. MAJETICH, Professor of Physics – Ph.D., University of Georgia; Carnegie Mellon, 1990–

RACHEL MANDELBAUM, Professor of Physics; Interim Department Head, Department of Physics – Ph.D., Princeton University; Carnegie Mellon, 2011–

CURTIS A. MEYER, Professor of Physics; Associate Dean, Mellon College of Science – Ph.D., University of California, Berkeley; Carnegie Mellon, 1993–

COLIN J. MORNINGSTAR, Professor of Physics – Ph.D., University of Toronto; Carnegie Mellon, 2000–

BRENDAN MULLAN, Associate Teaching Professor; Director of Undergraduate Laboratories, Department of Physics – Ph.D., Pennsylvania State University; Carnegie Mellon, 2024–

ANTONELLA PALMESE, Assistant Professor of Physics – Ph.D., University College London; Carnegie Mellon, 2022–

DIANA S. PARNO, Associate Professor of Physics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2017–

MANFRED PAULINI, Professor of Physics; Associate Dean, Mellon College of Science – Ph.D., University of Erlangen, Germany; Carnegie Mellon, 2000–

RICCARDO PENCO, Associate Professor of Physics – Ph.D., Syracuse University; Carnegie Mellon, 2018–

JEFFREY B. PETERSON, Professor of Physics – Ph.D., University of California, Berkeley; Carnegie Mellon, 1993–

RACHEL ROSEN, Associate Professor of Physics – Ph.D., New York University; Carnegie Mellon, 2023–

IRA Z. ROTHSTEIN, Professor of Physics – Ph.D., University of Maryland at College Park; Carnegie Mellon, 1997–

GILLIAN LYNN RYAN, Associate Teaching Professor of Physics; Director of Undergraduate Affairs, Department of Physics – Ph.D., Dalhousie University; Carnegie Mellon, 2020–

SUFEI SHI, Associate Professor of Physics – Ph.D., Cornell University; Carnegie Mellon, 2023–

FANGWEI SI, Assistant Professor of Physics – Ph.D., Johns Hopkins University; Carnegie Mellon, 2022–

SIMRANJEET SINGH, Assistant Professor of Physics – Ph.D., University of Central Florida; Carnegie Mellon, 2018–

GRIGORY TARNOPOLSKY, Assistant Professor of Physics – Ph.D., Princeton University; Carnegie Mellon, 2021–

HY TRAC, Associate Professor of Physics – Ph.D., University of Toronto; Carnegie Mellon, 2010–

MATTHEW WALKER, Associate Professor of Physics – Ph.D., University of Michigan; Carnegie Mellon, 2013–

MICHAEL WIDOM, Professor of Physics – Ph.D., University of Chicago; Carnegie Mellon, 1985–

Emeriti Faculty

LUC BERGER, Professor of Physics, Emeritus – Ph.D., University of Lausanne, Switzerland; Carnegie Mellon, 1960–

ARNOLD ENGLER, Professor of Physics, Emeritus – Ph.D., University of Berne, Switzerland; Carnegie Mellon, 1962–

THOMAS A. FERGUSON, Professor of Physics, Emeritus – Ph.D., University of California at Los Angeles; Carnegie Mellon; Carnegie Mellon, 1985–

JOHN G. FETKOVICH, Professor of Physics, Emeritus – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1959–

GREGG B. FRANKLIN, Professor of Physics – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1984–

STEPHEN GAROFF, Professor of Physics – Ph.D., Harvard ; Carnegie Mellon, 1988–

FREDERICK J. GILMAN, Professor of Physics, Emeritus – Ph.D., Princeton University; Carnegie Mellon, 1995–

RICHARD GRIFFITHS, Professor of Physics, Emeritus – Ph.D., University of Leicester, U.K.; Carnegie Mellon, 1996–

ROBERT GRIFFITHS, University Professor of Physics, Emeritus – Ph.D, Stanford University; Carnegie Mellon, 1962–

LEONARD S. KISSLINGER, Professor of Physics, Emeritus – Ph.D., Indiana University; Carnegie Mellon, 1969–

GEORGE KLEIN, Associate Teaching Professor of Physics – Ph.D., New York University; Carnegie Mellon, 1993–

ROBERT W. KRAEMER, Professor of Physics, Emeritus – Ph.D., Johns Hopkins University; Carnegie Mellon, 1965–

MICHAEL J. LEVINE, Professor of Physics, Emeritus – Ph.D., California Institute of Technology; Carnegie Mellon, 1968–

LING-FONG LI, Professor of Physics, Emeritus – Ph.D., University of Pennsylvania; Carnegie Mellon, 1974–

MATHIAS LOSCHE, Professor of Physics – Ph.D., Technical University of Munich; Carnegie Mellon, 2005–

JOHN F. NAGLE, Professor of Physics, Emeritus – Ph.D., Yale University; Carnegie Mellon, 1967–

BRIAN P. QUINN, Professor of Physics, Emeritus – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1988–

JAMES S. RUSS, Professor of Physics, Emeritus – Ph.D., Princeton University; Carnegie Mellon, 1967–

REINHARD SCHUMACHER, Professor of Physics, Emeritus – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1987–

ROBERT F. SEKERKA, University Professor of Physics and Mathematics, Emeritus – Ph.D., Harvard ; Carnegie Mellon, 1969–

ROBERT M. SUTER, Professor of Physics, Emeritus – Ph.D., Clark University; Carnegie Mellon, 1981–

ROBERT H. SWENDSEN, Professor of Physics, Emeritus – Ph.D., University of Pennsylvania; Carnegie Mellon, 1984–

STEPHANIE TRISTRAM-NAGLE, Research Professor of Physics, Emerita – Ph.D., University of California, Berkeley; Carnegie Mellon, 1986–

NED S. VANDER VEN, Professor of Physics, Emeritus – Ph.D., Princeton University; Carnegie Mellon, 1961–

HELMUT VOGEL, Professor of Physics, Emeritus – Ph.D. , University of Erlangen-Nuremberg; Carnegie Mellon, 1983–

Joint Appointments and Courtesy Appointments

SHELLEY ANNA, Professor of Chemical Engineering – Ph.D., Harvard University; Carnegie Mellon, 2003–

AXEL BRANDENBURG, Adjunct Professor of Physics – Ph.D., University of Helsinki; Carnegie Mellon, 2018–

SHIRLEY HO, Adjunct Associate Professor of Physics – Ph.D., Princeton University; Carnegie Mellon, 2012–

MOHAMMAD F. ISLAM, Associate Research Professor of Materials Science & Engineering – Ph.D., University of Pennsylvania; Carnegie Mellon, 2005–

NOA MAROM, Assistant Professor of Material Science and Engineering – Ph.D., Weizmann of Science; Carnegie Mellon, 2016–

MICHAEL E. MCHENRY, Professor of Materials Science and Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1989–

CARL RODRIGUEZ, Adjunct Professor of Physics – Ph.D., Northwestern University; Carnegie Mellon, 2023–

ANTHONY D. ROLLETT, Professor of Materials Science & Engineering – Ph.D., Drexel University; Carnegie Mellon, 1995–

MAREK SKOWRONSKI, Professor of Material Science and Engineering – Ph.D., Warsaw University; Carnegie Mellon, 1988–

VENKAT VISWANATHAN, Assistant Professor of Mechanical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2014–

HUAIYING ZHANG, Assistant Professor of Biological Sciences – Ph.D., McGill University; Carnegie Mellon, 2022–

JIAN-GANG ZHU, Professor of Electrical and Computer Engineering – Ph.D., University of California San Diego; Carnegie Mellon, 1997–

Department of Physics Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

33-100 Basic Experimental Physics

All Semesters: 6 units
This course provides students with a basic introduction to experimental physics. The content of the course and the particular experiments to be carried out are chosen to be especially useful for students who intend to work in the health sciences. Specific topics will range from mechanics to nuclear and atomic physics. This course is specifically geared toward pre-health students.

33-101 Physics First Year Seminar

Fall and Spring
Various seminars are offered that introduce first-year students to current topics of modern physics. These are mini courses that meet for half a semester. In the past, seminar topics have included: Science and Science Fiction, Astrophysics, Black Holes, Cosmology and Supernovae, Elementary Particles, and The Building Blocks of Matter. These seminars are open only to MCS first year students.

33-104 Experimental Physics

All Semesters: 9 units
This course provides first year students and sophomores with an introduction to the methods of experimental physics. Particular emphasis is placed on three aspects of experimentation: laboratory technique, including both the execution and the documentation of an experiment; data analysis, including the treatment of statistical and systematic errors and computer-aided analysis of experimental data; and written communication of experimental procedures and results. The concepts and skills for measurement and data analysis are acquired gradually through a series of experiments covering a range of topics from mechanics to nuclear and atomic physics.

33-114 Physics of Musical Sound

Spring: 9 units
An introduction to the physics and psychophysics of musical sound. Elementary physics of vibrating systems. Propagation of sound: traveling waves, reflection, and diffraction. Addition of waves: interference and beats. Anatomy of the ear and the perception of sound: loudness, pitch, and timbre. Standing waves and natural modes. Qualitative description of general periodic systems by Fourier analysis: the harmonic series and complex musical tones. The acoustics of musical instruments including percussion instruments, such as drums, bars, and struck and plucked strings; and instruments exhibiting self-sustained oscillations, including bowed strings, blown pipes, reeds, brasses, and singing. Intervals and consonance, musical scales, tuning and temperament. Basic room and auditorium acoustics. There are no formal prerequisites, but some previous musical experience will be useful.

33-115 Physics for Future Presidents

Fall: 9 units
Countless topics of social and political importance are intimately related to science in general and physics in particular. Examples include energy production, global warming, radioactivity, terrorism, and space travel. This course aims to provide key bits of knowledge based on which such issues can be discussed in a meaningful way, i.e., on the level of arguments and not just vague beliefs. We will cover an unusually wide range of topics, including energy, heat, gravity, atoms, radioactivity, chain reactions, electricity, magnetism, waves, light, weather, and climate. The course is open for all students at CMU.

33-120 Science and Science Fiction

Fall and Spring: 9 units
We will view and critique the science content in a selection of science fiction films, spanning more than 100 years of cinematic history, and from sci-fi TV shows from the past 50+ years. Guided by selected readings from current scientific literature, and aided by order-of-magnitude estimates and careful calculations, we will ponder whether the films are showing things which may fall into one of the following categories: Science fiction at the time of production, but currently possible, due to recent breakthroughs. Possible, in principle, but beyond our current technology. Impossible by any science we know. Topics to be covered include the future of the technological society, the physics of Star Trek, the nature of space and time, extraterrestrial intelligence, robotics and artificial intelligence, biotechnology and more.

33-121 Physics I for Science Students

Fall and Spring: 12 units
This calculus-based course combines the basic principles of mechanics with some quantum physics and relativity to explain nature on both a microscopic and macroscopic scale. The course will build models to describe the universe based on a small number of fundamental physics principles. Some simple computer modeling will be done to develop insight into the solving of problems using Newton's laws. Topics covered will include vectors, momentum, force, gravitation, oscillations, energy, quantum physics, center of mass motion, rotation, angular momentum, statistical physics, and the laws of thermodynamics. No computer experience is needed. Examples illustrating basic principles being presented will be taken from physics, chemistry, and biology. This course has a co-requisite of 21-120.

33-122 Physics II for Biological Sciences & Chemistry Students

Fall and Spring: 9 units
This is the second course in the introductory physics sequence for chemistry and biological science majors. The course will consist of eight portions covering (1) electrostatics and dynamics, (2) electrical circuits, (3) magnetism, (4) waves, (5) optics, (6) diffusive motion, and (7) hydrostatic forces and flow. Emphasis will be put on the application of the underlying physical principles in the study of biology and chemistry. This course has a co-requisite of 21-122.
Prerequisites: (33-121 and 21-120) or (33-151 and 21-120) or (33-141 and 21-120) or (33-111 and 21-120) or (33-131 and 21-120) or (33-106 and 21-120)

33-124 Introduction to Astronomy

Fall: 9 units
Astronomy continues to enjoy a golden age of exploration and discovery. This course presents a broad view of astronomy, straightforwardly descriptive and without any complex mathematics. The goal of the course is to encourage non-technical students to become scientifically literate and to appreciate new developments in the world of science, especially in the rapidly developing field of astronomy. Subjects covered include the solar system, stars, galaxies and the universe as a whole. The student should develop an appreciation of the ever-changing universe and our place within it. Computer laboratory exercises will be used to gain practical experience in astronomical techniques. In addition, small telescopes will be used to study the sky. This course is specifically geared toward non-science/engineering majors.

33-141 Physics I for Engineering Students

Fall and Spring: 12 units
This is a first semester, calculus-based introductory physics course. Basic principles of mechanics and thermodynamics are developed. Topics include vectors, displacement, velocity, acceleration, force, equilibrium, mass, Newton's laws, gravitation, work, energy, momentum, impulse, torque and angular momentum, temperature, heat, equations of state, thermodynamic processes, heat engines, refrigerators, first and second laws of thermodynamics, and the kinetic theory of gases. This course has a co-requisite of 21-120.

33-142 Physics II for Engineering and Physics Students

Fall and Spring: 12 units
This is the second half of a two-semester calculus-based introductory physics sequence for engineering and physics students. Two fifths of the course covers electricity, including electrostatics and electric fields, Gauss' law, electric potential, and simple circuits. Two fifths cover magnetism, including magnetic forces, magnetic fields, induction and electromagnetic radiation. One fifth of the course covers mechanical waves (including standing and traveling waves, superposition, and beats) and electromagnetic waves (including mode of propagation, speed, and other properties). This course has a co-requisite of 21-122.
Prerequisites: (33-106 and 21-120) or (33-141 and 21-120) or (21-120 and 33-111) or (33-131 and 21-120) or (33-151 and 21-120) or (21-120 and 33-121)

33-151 Matter and Interactions I

Fall: 12 units
For students with a strong physics background who are interested in using calculus-based mechanics to learn about topics such as dark matter, particle physics, and quantum phenomena, Matter and Interactions I provides an excellent alternative to Physics for Science Students. This course places great emphasis on constructing and using physical models, with a special focus on computer modeling to solve problems. Throughout the course, both traditional analytics techniques and scientific computing will be used to solve mechanical problems going from planetary systems, spring-based systems and nuclear scattering. Topics covered include Newton's Laws, microscopic models of solids, energy, energy quantization, mass-energy equivalence, multi particle systems, collisions, angular momentum including quantized angular momentum, kinetic theory of gases and statistical mechanics. Students conduct team research projects that will be presented at a departmental poster session at the end of the semester. This course has a co-requisite of 21-122.
Prerequisite: 21-120

33-152 Matter and Interactions II

Spring: 12 units
A more challenging alternative to 33-142, Physics II for Engineering and Physics Students. There is an emphasis on atomic-level description and analysis of matter and its electric and magnetic interactions. Topics include: Coulomb's law, polarization, electric field, plasmas, field of charge distributions, microscopic analysis of resistor and capacitor circuits, potential, macroscopic analysis of circuits, Gauss' law, magnetic field, atomic model of magnetism, Ampere's law, magnetic force, relativistic issues, magnetic induction with emphasis on non-Coulomb electric field, Maxwell's equations, electromagnetic radiation including its production and its effects on matter, re-radiation, interference. There will also be computer modeling, visualization and desktop experiments.
Prerequisites: (33-151 and 21-122) or (21-122 and 33-131)

33-201 Physics Sophomore Colloquium I

Fall: 2 units
This course (together with 33-202) is designed to give students an overview of the field of Physics and to help students make knowledgeable choices in both their academic and professional careers. We discuss several of the subfields of Physics in order to give students an understanding of the types of activities, from research to industrial applications, in each. Over the two semesters, we typically discuss six subfields in some detail with the goal of providing a minimal literacy in the relevant concepts and language. The course consists of one classroom lecture per week plus one hour per week of reading and/or problem solving.

33-202 Physics Sophomore Colloquium II

Spring: 2 units
This course is the second in a sequence (following 33-201) designed to give students an overview of the field of Physics and to help students make knowledgeable choices in both their academic and professional careers. We discuss several of the sub-fields of Physics in order to give students an understanding of the types of activities, from research to industrial applications, in each. Over the two semesters, we typically discuss six subfields in some detail with the goal of providing a minimal literacy in the relevant concepts and language. The course consists of one classroom lecture per week plus one hour per week of reading and/or problem solving.

33-211 Physics III: Modern Essentials

Fall and Spring: 10 units
Physics III is primarily for third-semester students of physics, including all physics majors, but is open to any qualified student who wants an introduction to the physics of the 20th century. The course will have a strong component of Special Relativity, dealing with kinematics and dynamics, but not electricity and magnetism. (See 33-213 description.) It will introduce students to a conceptual theory, which is mathematically simple but (initially) non-intuitive. The course also provides a broad exposure to quantum phenomena and early quantum theory without getting overly mathematical. It leads into the more formal Quantum Physics course (33-234).
Prerequisites: 33-112 or 33-152 or 33-132 or 33-142 or 33-107 or 33-122

33-213 Mini-Course in Special Relativity

Fall and Spring: 4 units
This course spans the first six weeks of 33-211, Physics III: Modern Essentials and should not be taking by students intending to major in physics. It treats the mechanics aspects of special relativity, including topics such as simultaneity, the Lorentz transformation, time dilation, length contraction, space-time geometry, resolving some famous puzzles, and the momentum, mass, and energy relations. The Electricity and Magnetism portions of the subject are deferred until the junior/senior courses in E and amp;M (33-338/33-339). Students may not take this class if they have successfully completed 33-211.
Prerequisites: 33-152 or 33-122 or 33-107 or 33-132 or 33-142 or 33-112

33-224 Stars, Galaxies and the Universe

Fall: 9 units
The study of astronomy has blossomed over the past few decades as a result of new ground-based and space-based telescopes, and with the advantage of fast computers for analysis of the huge quantities of data. As our astronomical horizon expands, we are still able to use the laws of physics to make sense of it all. This course is for students who want to understand the basic concepts in astronomy and what drives astronomical objects and the universe. The course emphasizes the application of a few physical principles to a variety of astronomical settings, from stars to galaxies to the structure and evolution of the universe. Introductory classical physics is required, but modern physics will be introduced as needed in the course. The course is intended for science and engineering majors as well as students in other disciplines with good technical backgrounds. Computer lab exercises will be used to gain practical experience in astronomical techniques. In addition, small telescopes are available for personal sign-out for those who would like to use them, and outdoor observing sessions will be organized as weather permits.
Prerequisites: 33-131 or 33-111 or 33-141 or 33-151 or 33-106 or 33-121

33-225 Quantum Physics and Structure of Matter

Fall: 9 units
This course introduces the basic theory used to describe the microscopic world of electrons, atoms, and photons. The duality between wave-like and particle-like phenomena is introduced along with the deBroglie relations which link them. We develop a wave description appropriate for quanta which are partially localized and discuss the interpretation of these wavefunctions. The wave equation of quantum mechanics is developed and applied to the hydrogen atom from which we extrapolate the structure of the Periodic Table. Other materials-related applications are developed, for example, Boltzmann and quantum statistics and properties of electrons in crystals. This course is intended primarily for non-physics majors who have not taken 33-211.
Prerequisites: 33-142 or 33-152 or 33-107 or 33-122 or 33-112 or 33-132

33-226 Physics of Energy

Spring: 9 units
This course will apply basic science, in particular introductory physics concepts, to a wide variety of topics related to energy. The course will closely follow a widely praised textbook The Physics of Energy, so be divided into 3 parts: basic energy science; energy sources; and climate. This course fills the breadth requirement for Physics Majors or can be used as one of the 4 electives required for the Applied Physics Track.
Prerequisites: 33-152 or 33-122 or 33-142

33-228 Electronics I

Spring: 10 units
An introductory laboratory and lecture course with emphasis on elementary circuit analysis, design, and testing. We start by introducing basic circuit elements and study the responses of combinations to DC and AC excitations. We then take up transistors and learn about biasing and the behavior of amplifier circuits. The many uses of operational amplifiers are examined and analyzed; general features of feedback systems are introduced in this context. Complex functions are used to analyze all of the above linear systems. Finally, we examine and build some simple digital integrated circuits.
Prerequisites: 33-112 or 33-132 or 33-107 or 33-142 or 33-152 or 33-122

33-231 Physical Analysis

Fall: 10 units
This course aims to develop analytical skills and mathematical modeling skills across a broad spectrum of physical phenomena, stressing analogies in behavior of a wide variety of systems. Specific topics include dimensional analysis and scaling in physical phenomena, exponential growth and decay, the harmonic oscillator with damping and driving forces, linear approximations of nonlinear systems, coupled oscillators, and wave motion. Necessary mathematical techniques, including differential equations, complex exponential functions, matrix algebra, and Taylor series, are introduced as needed.
Prerequisites: 21-122 and (33-142 or 33-122 or 33-152)

33-232 Mathematical Methods of Physics

Spring: 10 units
This course introduces, in the context of physical systems, a variety of mathematical tools and techniques that will be needed for later courses in the physics curriculum. Topics will include linear algebra, Fourier series and transforms, vector calculus with physical applications, and a first look at partial differential equations. The techniques taught here are useful in more advanced courses such as Physical Mechanics, Electricity and Magnetism, and Advanced Quantum Physics.
Prerequisite: 33-231

33-234 Quantum Physics

Spring: 10 units
An introduction to the fundamental principles and applications of quantum physics. A brief review of the experimental basis for quantization motivates the development of the Schrodinger wave equation. Several unbound and bound problems are treated in one dimension. The properties of angular momentum are developed and applied to central potentials in three dimensions. The one electron atom is then treated. Matrix description of quantum physics and the notion of spin are introduced. Properties of collections of indistinguishable particles are developed allowing an understanding of the structure of the Periodic Table of elements. A variety of mathematical tools are considered as needed.
Prerequisite: 33-211

33-241 Introduction to Computational Physics

Fall: 9 units
This undergraduate course will provide an introduction to the numerical methods and computational algorithms used to solve a variety of problems in physics. In introductory physics courses, you are able to derive analytical solutions for simpler problems and often with simplifying assumptions. Have you wondered if a numerical solution can be obtained for a more complex problem that has no closed-form analytical solution? Computational physics provides a modern and powerful approach to compliment classical approaches to problem solving. Today's and tomorrow's scientists must be computationally fluent to be competitive and successful. In this course, you will learn to formulate problems by applying physical principles, select and apply numerical methods, develop and apply computational algorithms, solve physical problems analytically and numerically, and visualize quantitative results using plotting software.
Prerequisites: 15-112 and 21-122 and 33-104 and (33-152 or 33-142 or 33-107 or 33-112 or 33-132 or 33-122)

33-301 Physics Upperclass Colloquium I

Fall: 1 unit
Junior and senior Physics majors meet together for 1 hour a week to hear discussions on current physics research from faculty, undergraduate and graduate students, and outside speakers. Other topics of interest such as application to graduate school, areas of industrial research and job opportunities will also be presented.

33-302 Physics Upperclass Colloquium II

Spring: 1 unit
Continuation of 33-301: Junior and senior Physics majors meet together for 1 hour a week to hear discussions on current physics research from faculty, undergraduate and graduate students, and outside speakers. Other topics of interest such as application to graduate school, areas of industrial research and job opportunities will also be presented.

33-331 Physical Mechanics I

Fall: 10 units
Fundamental concepts of classical mechanics. Conservation laws, momentum, energy, angular momentum, Lagrange's and Hamilton's equations, motion under a central force, scattering, cross section, and systems of particles.
Prerequisites: 33-231 and 33-232 and 21-259

33-332 Physical Mechanics II

Spring: 10 units
This is the second semester of a two-semester course on classical mechanics. The course will use the tools developed in 33-331 to examine motion in non-inertial reference frames; in particular, rotating frames. This then leads to the development of general rigid body motion, Euler's Equations. Finally, the course will cover coupled oscillations with particular emphasis on normal modes.
Prerequisite: 33-331

33-338 Intermediate Electricity and Magnetism I

Fall: 10 units
This course includes the basic concepts of electro- and magnetostatics. In electrostatics, topics include the electric field and potential for typical configurations, work and energy considerations, the method of images and solutions of Laplace's Equation, multipole expansions, and electrostatics in the presence of matter. In magnetostatics, the magnetic field and vector potential, magnetostatics in the presence of matter, properties of dia-, para- and ferromagnetic materials are developed.
Prerequisites: 33-231 and 21-259 and 33-232

33-339 Intermediate Electricity and Magnetism II

Spring: 10 units
This course focuses on electro- and magnetodynamics. Topics include Faraday's Law of induction, electromagnetic field momentum and energy, Maxwell's equations and electromagnetic waves including plane waves, waves in non-conducting and conducting media, reflection and refraction of waves, and guided waves. Electromagnetic radiation theory includes generation and characteristics of electric and magnetic dipole radiation. The Special Theory of Relativity is applied to electrodynamics: electric and magnetic fields in different reference frames, Lorentz transformations, four-vectors, invariants, and applications to particle mechanics.
Prerequisite: 33-338

33-340 Modern Physics Laboratory

Spring: 10 units
Emphasis is on hands-on experience observing important physical phenomena in the lab, advancing the student's experimental skills, developing sophisticated data analysis techniques, writing thorough reports, and improving verbal communication through several oral progress reports given during the semester and a comprehensive oral report on one experiment. Students perform three experiments which are drawn from the areas of atomic, condensed matter, classical, and nuclear and particle physics. Those currently available are the following: Zeeman effect, light scattering, optical pumping, thermal lensing, Raman scattering, chaos, magnetic susceptibility, nuclear magnetic resonance, electron spin resonance, X-ray diffraction, M and #246;ssbauer effect, neutron activation of radioactive nuclides, Compton scattering, and cosmic ray muons.
Prerequisites: 33-234 and (33-338 or 33-341 or 33-331)

33-341 Thermal Physics I

Fall: 10 units
The three laws of classical thermodynamics, which deal with the existence of state functions for energy and entropy and the entropy at the absolute zero of temperature, are developed along phenomenological lines. Elementary statistical mechanics is then introduced via the canonical ensemble to understand the interpretation of entropy in terms of probability and to calculate some thermodynamic quantities from simple models. These laws are applied to deduce relationships among heat capacities and other measureable quantities and then are generalized to open systems and their various auxiliary thermodynamic potentials; transformations between potentials are developed. Criteria for equilibrium of multicomponent systems are developed and applied to phase transformations and chemical reactions. Models of solutions are obtained by using statistical mechanics and are applied to deduce simple phase diagrams for ideal and regular solutions. The concept of thermodynamic stability is then introduced and illustrated in the context of phase transformations.
Prerequisites: 33-232 and 33-234 and 33-231

33-342 Thermal Physics II

Spring: 10 units
This course begins with a more systematic development of formal probability theory, with emphasis on generating functions, probability density functions and asymptotic approximations. Examples are taken from games of chance, geometric probabilities and radioactive decay. The connections between the ensembles of statistical mechanics (microcanonical, canonical and grand canonical) with the various thermodynamic potentials is developed for single component and multicomponent systems. Fermi-Dirac and Bose-Einstein statistics are reviewed. These principles are then applied to applications such as electronic specific heats, Einstein condensation, chemical reactions, phase transformations, mean field theories, binary phase diagrams, paramagnetism, ferromagnetism, defects, semiconductors and fluctuation phenomena.
Prerequisite: 33-341

33-350 Undergraduate Research

Fall and Spring
Open to sophomore, junior, and senior physics majors. The student undertakes a project of interest under the supervision of a faculty member for 3 to 9 units of credit. May include research done in a research lab, extending the capabilities of a teaching lab, or a theoretical or computational physics project. The student experiences the less structured atmosphere of a research program where there is much room for independent initiative. Student should contact faculty directly to inquire about opportunities. Registration requires approval of the Director of Undergraduate Affairs.

33-353 Intermediate Optics

Fall: 12 units
Offered alternative years. Geometrical optics: reflection and refraction, mirrors, prisms, lenses, apertures and stops, simple optical instruments, fiber optics. Scalar wave optics: wave properties of light, interference, coherence, interferometry, Huygens-Fresnel principle, Fraunhofer diffraction, resolution of optical instruments, Fourier optics, Fresnel diffraction. Laser beam optics: Gaussian beams. Vector wave optics: electromagnetic waves at dielectric interfaces, polarized light. The course will use complex exponential representations of electromagnetic waves.
Prerequisites: 33-122 or 33-142 or 33-112 or 33-132 or 33-107 or 33-152

33-355 Nanoscience and Nanotechnology

Fall: 9 units
This course will explore the underlying science behind nanotechnology, the tools used to create and characterize nanostructures, and potential applications of such devices. Material will be presented on a level intended for upper-level science and engineering students. The course will start with a survey of physics at different length scales, and introduce the application of elementary quantum mechanics and solid-state physics to nanoscience and nanotechnology. Characterization using electron microscopy, scanning probe methods, and spectroscopic techniques will then be described in detail. Fabrication using top-down and bottom-up methods will be discussed, contrasting these approaches and providing examples of each. Nanotechnology methods will be compared with those used in the modern microelectronics industry. Finally, examples of nanoscale components and systems will be described, which may include semiconductor heterostructures; nanotubes and graphene; single-electron transistors; nanoscale magnetic devices; photonic devices; nanofluidic devices; nano electrical-mechanical systems (NEMS); and superconducting devices. There will be time allocated to other topics, with the mutual agreement of the instructor and the class. Stand-alone laboratory exercises will be included as an important element of the course. These will focus on the use of scanning probe methods to study the nm-scale structure and atomic forces involved in various nanostructures as well as micro-scale patterning using photolithography. In addition to the prerequisites, students should have taken a prior laboratory course in a science or engineering department and should have some familiarity with differential equations at an elementary level.
Prerequisites: 33-234 or 33-225

33-398 Special Topics

Fall: 9 units
The description of most all physical systems relies on the concept of a manifold. In addition to the space-time manifold, which plays the role of the stage upon which the dynamics plays out, many systems involve target spaces which are manifolds. These target spaces are typically Lie Groups. A classic example of such a system is the rigid rotator, where every configuration of the system is a point on the manifold which defines the group of rotations. The purpose of this class will be to learn the basics of differential geometry and apply these ideas to physical systems. Topics will include Hamiltonian dynamics, fluid mechanics as well as gauge theories. Requirements: Knowledge of Linear Algebra. No prior knowledge of group theory will be expected.
Prerequisites: (21-260 or 33-231) and 21-341

33-441 Introduction to Biophysics

Fall: 10 units
Biological physics, or the physics of living systems, is an exciting interdisciplinary frontier of physics that aims to understand the phenomenon of life using concepts and tools from Physics. This intermediate level course will introduce the general concepts and principles underpinning the physical behavior of living systems, from the dynamics of proteins and molecules to collective behavior of living cells and organisms. The course will develop key physics concepts that are most vital to biological processes, including energy conversion, information transfer, mechanics of movement, statistical phenomena, and fluid flow. We will apply these physics concepts to demonstrate how biological systems function, build simplified mathematical models to predict behavior, and use experimental data to inform and test models. The integration of biological phenomena, physical concepts, mathematical modeling, and analysis of experimental data represents an entirely new mode of learning, based on strategies adopted in research. These strategies will break traditional disciplinary barriers between physics and biology. The students will be expected to gain an intuitive grasp of ways to: frame the physical problem, identify appropriate theoretical frameworks, analyze experimental data, and ways to generalize and to understand the dependence of biophysical phenomenon on time and length scales. No prior knowledge of biology is expected. This class is offered in Fall of even years (e.g. Fall '24, 26, etc.)
Prerequisites: 33-142 or 33-112 or 33-152 or 33-107 or 33-132 or 33-122

33-444 Introduction to Nuclear and Particle Physics

Spring: 9 units
Description of our understanding of nuclei, elementary particles, and quarks, with equal emphasis on the nuclear and particle aspects of sub-atomic matter. We discuss the physics of accelerators, and how particle interactions with matter lead to various kinds of detector instrumentation. Then we discuss methods for measuring sub-atomic structure, symmetries and conservation laws, and the electromagnetic, weak, and strong interactions. We examine the quark model of the mesons and baryons, as well as several models of the atomic nucleus. This class is offered in Spring of even years (e.g. Spring '24, '26, etc.)
Prerequisites: 33-234 and 33-338

33-445 Advanced Quantum Physics I

Fall: 9 units
Mathematics of quantum theory, linear algebra and Hilbert spaces; review of classical mechanics; problems with classical mechanics; postulates of quantum theory; one dimensional applications; the harmonic oscillator; uncertainty relations; systems with N degrees of freedom, multi-particle states, identical particles; approximation methods. This course has a co-requisite of 33-331.
Prerequisite: 33-234

33-446 Advanced Quantum Physics II

Spring: 9 units
Classical symmetries; quantum symmetries; rotations and angular momentum; spin; addition of angular momentum; the hydrogen atom; quantum "paradoxes" and Bell's theorem; applications.
Prerequisite: 33-445

33-448 Introduction to Solid State Physics

Spring: 9 units
This course gives a quantitative description of crystal lattices, common crystal structures obtained by adding a basis of atoms to the lattice, and the definition and properties of the reciprocal lattice. Diffraction measurements are studied as tools to quantify crystal lattices, including Bragg's law and structure factors. Diffraction from amorphous substances and liquids is also introduced. The various types of atomic bonding, e.g., Van der Waals, metallic, ionic, covalent and hydrogen are surveyed. Binding energies of some crystalline structures are calculated. Models of crystal binding are generalized to include dynamics, first for classical lattice vibrations and then for quantized lattice vibrations known as phonons. These concepts are used to calculate the heat capacities of insulating crystals, to introduce the concept of density of states, and to discuss phonon scattering.
The band theory of solids is developed, starting with the free electron model of a metal and culminating with the properties of conductors and semiconductors. Magnetic phenomena such as paramagnetism and the mean field theory of ferromagnetism are covered to the extent that time permits.
Prerequisites: 33-341 and (33-225 or 33-234)

33-451 Senior Research

Fall and Spring
Open to all senior physics majors. May include research done in a research lab, extending the capabilities of a teaching lab, or a theoretical or computational physics project for 3 to 9 units of credit. The student experiences the less structured atmosphere of a research program where there is much room for independent initiative. Modern Physics Laboratory, 33-340, should precede this course, though it is not required. Student should contact faculty directly to inquire about opportunities. Registration requires approval of the Director of Undergraduate Affairs.

33-456 Advanced Computational Physics

Spring: 9 units
This course uses techniques covered in Introduction to Computational Physics as a foundation. Major topics in the course will be Data Science, Parallel Computing and Machine Learning with applications from astrophysics, thermodynamics, orbital mechanics and other domains.
The course will introduce professional practices such as compiling and optimizing code, using software development environments and software engineering. Students will gain a practical knowledge of current computing hardware design, the C computer language, the TensorFlow deep learning framework and the Spark big data platform, while using a Linux supercomputing environment.
Prerequisite: 33-241

33-466 Extragalactic Astrophysics and Cosmology

Spring: 9 units
Starting from the expanding universe of galaxies, this course lays out the structure of the universe from the Local Group of galaxies to the largest structures observed. The observational pinnacle of the Big Bang theory, the microwave background radiation, is shown to provide us with many clues to conditions in the early universe and to the parameters which control the expansion and fate of the universe. Current theories for the development of galaxies and clusters of galaxies are outlined in terms of our current understanding of dark matter. Observational cosmology continues to enjoy a golden era of discovery and the latest observational results will be interpreted in terms of the basic cosmological parameters.
Prerequisites: 33-224 and 33-234

33-467 Astrophysics of Stars and the Galaxy

Fall: 9 units
The physics of stars is introduced from first principles, leading from star formation to nuclear fusion to late stellar evolution and the end points of stars: white dwarfs, neutron stars and black holes. The theory of stellar structure and evolution is elegant and impressively powerful, bringing together all branches of physics to predict the life cycles of the stars. The basic physical processes in the interstellar medium will also be described, and the role of multi-wavelength astronomy will be used to illustrate our understanding of the structure of the Milky Way Galaxy, from the massive black hole at the center to the halo of dark matter which emcompasses it. This class is offered in Fall of odd years (e.g. Fall '23, 25, etc.)
Prerequisites: 33-224 and 33-234

33-499 Supervised Reading

Fall and Spring
Physics majors may explore a certain area of advanced physics under the direct supervision of a faculty member for up to 9 units of credit. Special permission is required from the Director for Undergraduate Affairs to register. The student must contact a faculty member directly to inquire about opportunities, and to develop a written plan that includes a list of topics to be covered, expectations of student time and/or work, as well as a description of how student learning will be evaluated. The Director of Undergraduate Affairs will review this plan and students will be registered only if the plan is approved.

33-650 General Relativity

Fall: 9 units
General Relativity is the classical theory of gravity. It is widely recognized as a beautiful theory - equating gravity and the geometry of spacetime leads to a profound conceptual change in the way we regard the universe. The predictions of the theory are relevant to systems as varied as high precision measurements of the earth's gravitational field or the strongly curved space-times around black holes. In this course, we will gradually develop an understanding of the geometries which are the solutions of the Einstein equation, with an emphasis on their relevance to physical situations. We will motivate the theory step by step and eventually introduce the Einstein equation itself.
Prerequisites: 33-211 and 33-339

33-658 Quantum Computation and Quantum Information Theory

Fall: 10 units
This course provides an overview of recent developments in quantum computation and quantum information theory. The topics include: a review of relevant concepts in quantum mechanics and in information theory. It will then cover quantum channels, both ideal and noisy, quantum cryptography, an introduction to computational complexity, Shors factorization algorithm, Grovers search algorithm, and proposals for the physical realization of quantum devices, such as correlated photons, ions in traps, and nuclear magnetic resonance. It will also include hands-on experience running programs on cloud quantum computers.
Prerequisite: 33-234 Min. grade B

33-659 Quantum Hall Effect and Topological Insulators

Intermittent: 12 units
This course will introduce students to the topic of topological insulators and related phenomena using the Berry phase a unifying concept. In the first half of the semester, we will cover basic concepts such as Berry phase, Dirac fermions, Hall conductance and its link to topology, and the Hofstadter problem of lattice electrons in a magnetic field. Linear response theory will be discussed in relation to the Hall conductance. In the second half, we will move on to explain topological phases of matter such as Chern insulators and two- and three-dimensional topological insulators. Various techniques to calculate the topological indices will be introduced and connection to real materials will be discussed. Numerical studies of various tight-binding models provide intuitive understandings and will be an essential part of this course.
Prerequisite: 33-448

33-755 Quantum Mechanics I

Fall: 12 units
This course introduces fundamental concepts of quantum mechanics. Applications are made to quantum computing, the harmonic oscillator, the hydrogen atom, electron spin and addition of angular momentum.
Prerequisite: 33-446

33-756 Quantum Mechanics II

Spring: 12 units
This course focuses on qualitative and approximation methods in quantum mechanics, including time-independent and time-dependent perturbation theory, scattering and semiclassical methods. Applications are made to atomic, molecular and solid matter. Systems of identical particles are treated including many electron atoms and the Fermi gas. Prerequisite: 33-755, Quantum Mechanics I; 33-759 Theoretical Physics. 3 hrs. lecture. Typical Text: Cohen-Tannoudji Quantum Mechanics, volume 2.
Prerequisites: 33-755 and 33-759

33-758 Quantum Computation and Quantum Information Theory

Spring: 12 units
This course, taught in collaboration with the Computer Science Department, provides an overview of recent developments in quantum computation and quantum information theory. The topics include: an introduction to quantum mechanics, quantum channels, both ideal and noisy, quantum cryptography, an introduction to computational complexity, Shor's factorization algorithm, Grover's search algorithm, and proposals for the physical realization of quantum devices, such as correlated photons, ions in traps, and nuclear magnetic resonance. The textbook is Nielsen and Chuang, Quantum Computation and Quantum Information. 3 hrs. lecture plus weekly seminar. A 10 unit version of the course, 33-658, does not include the seminar.

33-759 Introduction to Mathematical Physics I

Fall: 12 units
This course is an introduction to methods of mathematical analysis used in solving physical problems. Emphasis is placed both upon the generality of the methods, through a variety of sample problems, and upon their underlying principles. Topics normally covered include matrix algebra (normal modes, diagonalization, symmetry properties), complex variables and analytic functions, differential equations (Laplace's equation and separation of variables, special functions and their analytic properties), orthogonal systems of functions.
Prerequisite: 33-232

33-761 Classical Electrodynamics I

Fall: 12 units
This course deals with the static and dynamic properties of the electromagnetic field as described by Maxwell's equations. Among the topics emphasized are solutions of Laplace's, Poisson's and wave equations, effects of boundaries, Green's functions, multipole expansions, emission and propagation of electromagnetic radiation and the response of dielectrics, metals, magnetizable bodies to fields.
Prerequisite: 33-339

33-762 Classical Electrodynamics II

Spring: 12 units
The applications of electromagnetic theory to various physical systems is the main emphasis of this course. The topics discussed include the theory of wave guides, scattering of electromagnetic waves, index of refraction, special relativity and foundation of optics. 3 hrs. lecture. Typical Text: Jackson, Classical Electrodynamics. 2nd Ed.

33-765 Statistical Mechanics

Spring: 12 units
This course develops the methods of statistical mechanics and uses them to calculate observable properties of systems in thermodynamic equilibrium. Topics treated include the principles of classical thermodynamics, canonical and grand canonical ensembles for classical and quantum mechanical systems, partition functions and statistical thermodynamics, fluctuations, ideal gases of quanta, atoms and polyatomic molecules, degeneracy of Fermi and Bose gases, chemical equilibrium, ideal paramagnetics and introduction to simple interacting systems. 3 hrs. lecture, 1 hr. recitation. Typical Texts: Swendsen, An Introduction to Statistical Mechanics and Thermodynamics; Kardar, Statistical Physics of Particles; McQuarrie, Statistical Mechanics

33-767 Biophysics: From Basic Concepts to Current Research

Spring: 12 units
This course mixes lectures and student presentations on advanced topics in Biological Physics. In the course, students will gain a deep appreciation of the fact that very basic physical and chemical principles underlie many central life processes. Life is not only compatible with the laws of physics and chemistry, rather, it exploits them in ingenious ways. After taking the course, students should be able to name examples of such situations for which they can provide a coherent line of reasoning that outlines these connections. They will be able to explain key experiments by which these connections either have been found or are nowadays routinely established, and outline simple back-of-the-envelope estimates by which one can convince oneself of either the validity or inapplicability of certain popular models and ideas. They should also have become sufficiently familiar with the key terminology frequently encountered in biology, such that they can start to further educate themselves by consulting biological and biophysical literature. The course uses Physical Biology of the Cell by Rob Phillips et al. (Garland Science, New York, NY, 2013, ISBN 978-0-8153-4450-6).

33-769 Quantum Mechanics III: Many Body and Relativistic Systems

Fall: 12 units
The first main theme of this course is quantum mechanics applied to selected many-body problems in atomic, nuclear and condensed matter physics. The second main theme is relativistic quantum mechanics. Creation and annihilation operators are introduced and used to discuss Hartree-Fock theory as well as electromagnetic radiation. The Dirac equation is introduced and applied to the hydrogen atom. Prerequisite: 33-756, 33-76l. 3 hrs. lecture
Prerequisites: 33-761 and 33-756

33-770 Field Theory I

Fall: 12 units
This course gives systematic studies of the relativistic field theories. Topics included are canonical quantization of fields, LSZ reduction formula, Feynman diagram techniques, application to quantum electrodynamics and the discussion of the methods of renormalization.
Prerequisite: 33-756

33-771 Field Theory II

All Semesters: 12 units
Missing Course Description - please contact the teaching department.

33-775 Introduction to Research 1

Fall: 12 units
Both semesters are designed to give the student opportunity to gain experience in modern experimental techniques either through participation in research laboratories or through formal instruction, depending on the student's background. In the first semester, the student will also learn of the research of the department through lectures by the faculty on their work. All students are required to take the first semester, but those with post-graduate or unusual laboratory experience may not be required to take the second. However, it should be noted that for the M.S. degree, 12 units of laboratory are required.

33-777 Introductory Astrophysics

Fall: 12 units
Introductory Astrophysics is survey course with a mix of observational and theoretical investigations into astrophysical systems across a range of scales, covering planetary physics (solar system and extrasolar planets), stellar structure/evolution, Milky Way, extragalactic astrophysics, and cosmology.

33-778 Introduction to Cosmology

Fall: 12 units
An introduction to modern cosmology that includes detailed description of the smooth expanding universe (e.g., nucleosynthesis, the cosmic microwave background, and dark matter) and the perturbations that translate into the large scale structure of the universe.
Prerequisites: 33-331 and 33-341

33-779 Introduction to Nuclear and Particle Physics

Fall: 12 units
An introduction to the physics of atomic nuclei and elementary particles. This course is suitable as a one-semester course for students not specializing in this area and also provides an introduction to further work in 33-780, 33-78l. Topics included are symmetry principles of strong and weak interactions, quark model, classification of particles and nuclear forces.

33-780 Nuclear and Particle Physics II

Spring: 12 units
This course covers the phenomenology of weak interactions, parton model for the deep inelastic scattering, and introduction to gauge theories of weak and electromagnetic interactions. Various topics of current interest in particle physics will also be included. Prerequisite: 33-779, 33-770 (or concurrently). 3 hrs. lecture.
Prerequisites: 33-779 and 33-770

33-783 Solid State Physics

Fall: 12 units
This course is designed to give advanced graduate students a fundamental knowledge of the microscopic properties of solids in terms of molecular and atomic theory, crystal structures, x-ray diffraction of crystals and crystal defects, lattice vibration and thermal properties of crystals; free-electron model, energy bands, electrical conduction and magnetism.
Prerequisite: 33-756 Min. grade B

MCS Interdisciplinary Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

38-100 CATALYST - MCS First-Year Seminar

Fall and Spring: 3 units
The CATALYST seminar will equip transfer students to MCS, as well as those students who did not successfully complete the EUREKA seminar, with foundational knowledge, skills and perspectives that will support their development as emerging scientists and scholars. During the seminar, students will be presented with opportunities and experiences designed to help them frame how the MCS curriculum aspires to shape their evolving identities in the areas of scholar, person, professional and citizen, while also engendering a sense of excitement about science and scientific inquiry. The seminar will offer information and strategies that are employed both by successful students and by successful scientists in optimizing their approach to work and life, with a key focus on areas such as cognitive learning skills, research, teamwork, goal setting, time management, community engagement, ethics, resources and assessment. Additionally, the seminar will introduce students to the learning outcomes and requirements associated with the MCS core curriculum, with a particular emphasis on the self-directed ENGAGE courses and the role of the MyCORE e-portfolio system in documenting and framing student growth and development.

38-101 EUREKA!: Discovery and Its Impact

Fall: 6 units
The MCS first-year seminar "EUREKA: Discovery and Its Impact" will equip new students with foundational knowledge, skills and perspectives that will support their development as emerging scientists. During the seminar, students will be presented with opportunities and experiences designed to help them frame how the MCS curriculum aspires to shape their evolving identities in the areas of scholar, person, professional and citizen, while also engendering a sense of excitement about science and scientific inquiry. The seminar will offer information and strategies that are employed both by successful students and by successful scientists in optimizing their approach to work and life, with a key focus on areas such as cognitive learning skills, research, teamwork, goal setting, time management, innovation, community engagement, ethics, resources and assessment. Additionally, the seminar will introduce first-year students to the learning outcomes and requirements associated with the MCS core curriculum, with a particular emphasis on the self-directed ENGAGE courses and the role of the e-portfolio system in documenting and framing student growth and development. Students who are enrolled in FADS are encouraged to enroll in a recitation section taught in the Mellon Institute.

38-110 ENGAGE in Service

All Semesters: 1 unit
ENGAGE in Service is a 1-unit course (9 hours of work, minimum requirement for a passing grade) designed to promote MCS students' direct engagement with community development and service learning. To fulfill this requirement, students must engage in a minimum of 9 hours of work devoted to a non-profit organization or organizations of their choice, 3 of which must have a direct benefit to the local Pittsburgh community. Students may complete the requirements anytime during their undergraduate years, but must register for the class during the semester that they intend to complete it, no later than their penultimate semester. Coursework includes documentation of service via completion of a form for each eligible activity that includes a time log, a description of the activity, the name and contact information for their supervisor and the supervisor's signature. In addition, during the last semester of the project/course students will prepare a 1-2 page reflective paper on the lessons learned from their immersion in the organization(s) and its (their) work. No pay or other compensation can be received, and, in special cases, students may petition for a waiver if they have completed another service-learning course at Carnegie Mellon.

38-132 DC Grand Challenge First-Year Seminar: Health in Unhealthy Times: Preventing, Ma

Intermittent: 9 units
We live in times when health is a major global concern, whether we worry about the development of novel Covid-19 mutations or continue to grapple with chronic illnesses such as obesity, diabetes, autoimmune diseases, cancer as well as depression and anxiety. Health and illness are key drivers of the human experience. And yet, health is fundamentally impacted by different human experiences. This first year Grand Challenges seminar will introduce students to core concepts in the life sciences that will enable them to better appreciate the scientific aspects of health. Building on this knowledge, students will then explore important psychosocial determinants, ethical constraints, and historical roots of health. Students will also develop a familiarity with the cultural and communicative skills required to argue about health, make decisions, and engage empathically with others in their health stories. We will read and discuss a broad variety of materials from medical science articles to social psychological experimental reports and personal or literary narratives about health. The course is divided into three components: health and preventative behaviors; coping with disruptive health experiences; managing chronic health challenges. We will provide a broad overview for each category, followed by a deep dive focused on particular health issues: diet and exercise (prevention); anxiety and depression (management); epidemics/Covid-19/cancer (disruption). Given the broad array of topics discussed, we believe these components can engage students on a personal level.

38-220 ENGAGE in the Arts

Fall and Spring: 2 units
ENGAGE in the Arts is part of Mellon College of Science's Core Curriculum. In this 2-unit full-semester course, students will broaden their knowledge of the fine arts, extend their global and cultural awareness, and facilitate the further development of their self-identity. Coursework requires that students attend 8 distinct arts events, 2 of which must engage with a culture different from one's personal cultural background. In choosing events, students should be imbued with an attitude of openness to new ideas and a willingness to try something new. The course requires students to share, reflect, and document their participation in a variety of arts events by engaging with classmates and instructors through MyCORE, where they can upload coursework and find postings for events. Coursework can be completed at any time during students' undergraduate years, but they must register for the class during the semester that they intend to complete it, no later than their penultimate semester.

38-230 ENGAGE in Wellness: Looking Inward

Spring: 1 unit
ENGAGE in Wellness: Looking Inward is a 1-unit mini-course that MCS students will enroll in the spring of the sophomore year, designed to give students a holistic understanding of their own personal wellness. The course is structured around the concept of a Wellness Wheel, a model for personal wellness that is used to describe the various areas that students should reflect upon when describing, and ultimately improving, their overall wellness. The MCS Wellness Wheel has nine components: intellectual, physical, emotional, spiritual, environmental, institutional or community, financial, social, and occupational health. During this first course, taken in the first mini of the sophomore year, students will select one of three areas on which to focus: intellectual, emotional or physical health. They will be asked to engage in a recursive, reflective process to assess their own level of wellness in this area, develop short-term goals for the next year and a statement of a longer-term goal in this area, identify possible resources and then choose activities that promote this aspect of wellness. Students should expect to devote 9-14 hours to the development and articulation of their plan in order to earn a passing grade. These hours are tied to completion of the requested assessments and not to the activities students' elect to pursue in fulfillment of their wellness plan. THIS COURSE IS FOR SOPHOMORES ONLY.

38-301 PROPEL

Spring: 6 units
PROPEL: Preparation, Readiness, and Optimization for Professional Excellence in Life - is a 6-unit seminar course that MCS students will enroll in the spring of their junior year. The course will leverage students' deepening disciplinary perspective in service of the development of competencies, skills and perspectives that are necessary to achieve professional excellence in today's society. The course will use traditional career development activities, such as interviewing, resume writing and networking, as a starting point for students to begin the process of reflecting on, and preparing for, their impending transitions into professional life. From there, the course will seek to expand students' conceptualization of the scientific workplace by exploring the interplay of science, innovation, public policy, entrepreneurism and business in professional settings today. The seminar will also equip students with significant insight into the ways in which global policy, societal and political forces, environmental issues and ethical considerations shape and influence the activity and research of working scientists. The course will offer additional experiences for students to refine their multidisciplinary teamwork and communication skills via small group projects focusing on the aforementioned course themes. Finally, "PROPEL" will include a formal academic advising component to ensure that all students are well positioned to complete the MCS core requirements and departmental requirements in the following year. THIS COURSE IS FOR QBS JUNIORS ONLY.

38-304 Reading and Writing Science

Spring: 6 units
This course is designed to hone the student's ability to read scientific writing and to communicate about scientific topics to audiences with different levels of interest and expertise in science. This course introduces students to frameworks for identifying the linguistic features of scientific argumentation in research papers across a range of scientific disciplines to improve their reading and writing of scientific content. The course also examines how scientific information changes when it is reported in the popular media and the effects these changes have on non-experts' understanding of science. Students will use these changes as a model for writing about scientific research to non-expert audiences. Finally, this course gives students the opportunity to practice science communication by creating oral presentations for their peers. The curriculum in this course is drawn from rhetoric: a discipline focused on the analysis and production of language, arrangement, and argument strategically designed to persuade an audience.

38-330 ENGAGE in Wellness: Looking Outward

Fall and Spring: 1 unit
ENGAGE in Wellness: Looking Outward is a 1-unit mini-course that MCS students will enroll in the fall of the junior year, designed to give students a holistic understanding of their own personal wellness. The course is structured around the concept of a Wellness Wheel, a model for personal wellness that is used to describe the various areas that students should reflect upon when describing, and ultimately improving, their overall wellness. The MCS Wellness Wheel has nine components: intellectual, physical, emotional, spiritual, environmental, institutional or community, financial, social, and occupational health. During this second course, taken in the first mini of the junior year, students will select one of three areas on which to focus: spiritual, environmental and institutional or community health. They will be asked to engage in a recursive, reflective process to assess their own level of wellness, participate in wellness activities on campus or develop short-term goals and longer-term goal in this area, and identify possible resources that promote this aspect of wellness. Students should expect to devote 9-14 hours to the development and articulation of their plan in order to earn a passing grade. These hours are tied to completion of the requested assessments and not to the activities students' elect to pursue in fulfillment of their wellness plan. THIS COURSE IS FOR JUNIORS ONLY.

38-402 MCS Leadership Development Seminar

Fall and Spring: 9 units
This course is designed for 3rd-year and 4th-year Mellon College of Science students committed to further developing their leadership skills and potential for sustained impact in the future. The course will be substantive and engaging, while also ideally thought provoking, edifying, and enjoyable. The course will build on the foundation of six key leadership pillars, identified to hone each students professional and personal development to serve others, and to seek out and nurture opportunities to heighten ones capacity as a person and leader who is: VISIONARY, with clear goals for yourself, your organizations and communities, and others in whose lives you are a part, including the broader society; ETHICAL, with core values and steadfastness in the face of competing objectives, and the resilience to deal with conflicts without moral compromise; ENGAGING, with empathy, attentive interpersonal attributes, outstanding formal and informal communication skills, and the capacity to inspire; TACTICAL, with an ability to operationalize big ideas and bring them to fruition, creating the ideal environment for individual and group success; TECHNICAL, based on your own high-level skill set and the ego strength for inclusion of others with complementary realms of expertise; REFLECTIVE, manifesting in the honest appraisal of personal and organizational success against metrics, and the ability to redirect based on assessment.

38-430 ENGAGE in Wellness: Looking Forward

Fall and Spring: 1 unit
ENGAGE in Wellness: Looking Forward is a 1-unit mini-course that MCS students will enroll in the fall of the senior year, designed to give students a holistic understanding of their own personal wellness. The course is structured around the concept of a Wellness Wheel, a model for personal wellness that is used to describe the various areas that students should reflect upon when describing, and ultimately improving, their overall wellness. The MCS Wellness Wheel has nine components: intellectual, physical, emotional, spiritual, environmental, institutional or community, financial, social, and occupational health. During this third course, taken in the first mini of the senior year, students will select one of three areas on which to focus: financial, social and occupational health. They will be asked to engage in a recursive, reflective process to assess their own level of wellness, participate in wellness activities on campus or develop short-term goals and longer-term goal in this area, and identify possible resources that promote this aspect of wellness. Students should expect to devote 9-14 hours to the development and articulation of their plan in order to earn a passing grade. These hours are tied to completion of the requested assessments and not to the activities students' elect to pursue in fulfillment of their wellness plan. THIS COURSE IS FOR SENIORS ONLY.

Minors Offered by the Mellon College of Science

The Mellon College of Science offers several minors to students interested in broadening their scientific training or acquiring a level of expertise in a particular scientific field. The intercollege minors described below are designed to supplement your degree in science; the departmental minors offer you a means of exploring another field and are open to students throughout the university.

Intercollege Minors

Please see the descriptions below.

- Environmental and Sustainability Studies
- Health Care Policy and Management
- Scientific Computing

Departmental Minors in the Mellon College of Science

For descriptions, please see the departmental sections which follow.

- Biological Sciences
- Chemistry
- Computational Finance
- Discrete Mathematics and Logic
- Mathematical Sciences
- Neuroscience
- Physics

Minor in Environmental and Sustainability Studies

Maggie Braun, *MCS Associate Dean for Undergraduate Affairs*
Abigail Owen, Program Director and *Faculty Advisor, Steinbrenner Institute for Environmental Education and Research*

Please see the Intercollege Section (p.) of the catalog for details about this minor.

Minor in Health Care Policy and Management

Sponsored by:
Heinz College of Information Systems and Public Policy
Dietrich College of Humanities and Social Sciences
Mellon College of Science

Faculty Advisors:
Jason D'Antonio, Mellon College of Science
James F. Jordan, H. John Heinz III College

The face of health care is changing. The practice of medicine is being fundamentally altered by the forces of change in public policy, health care organizations and in the industry as a whole. The role of individual professionals in this industry is changing as rapidly as the industry itself. Traditional career paths have disappeared overnight to be replaced by new opportunities that require new skills. New organizations are placing new demands on their professional and medical staffs. The criteria of efficiency and financial stability are entering the domains of diagnosis and treatment.

This minor is designed to provide students considering a career in the health professions with an understanding of how these changes are likely to affect their careers. Students will become familiar with the critical policy and management issues and will begin to learn to operate effectively in the emerging health care environment. The curriculum combines economic, organizational, managerial, historical and psychological perspectives on these issues to provide a foundation for a deepened understanding of the changing structure of health care organizations and policy.

Required Courses for HCPM Minor

A total of 54 units are required to complete this minor. Entry into the minor requires completion of 73-102 Principles of Microeconomics or the equivalent by approval.

Required Courses

Complete a total of 21 units from the following:		
79-330	Medicine and Society: Health, Healers, and Hospitals	9
90-436	Health Systems	6
90-472	Health Policy	6

Elective Courses

Complete a minimum of 24 units from these two sections:

Heinz College Courses		
94-409	Healthcare Information Systems	12
73-328	Health Economics	12
90-832	Health Law	6
90-433	Population Health	6
90-834	Health Care Geographical Information Systems	12
Other courses as approved		

Humanities and Social Sciences Courses (9 units each)		
80-245	Medical Ethics	9
76-494	Healthcare Communications	9
88-365	Behavioral Economics and Public Policy	9
42-444	Medical Devices	9
Other courses as approved		

Please note that some of these courses have prerequisites that will not count toward the completion of the requirements for this minor.

Elective Focus Areas

Focus areas are suggested groupings of electives based on student interest. Students *do not* need to take all electives within one focus area; they are free to choose their 18-unit elective minimum from any combination of focus areas.

Health Management/Administration Focus		Units
90-832	Health Law	6
80-245	Medical Ethics	9
76-494	Healthcare Communications	9

Health Policy Focus		Units
73-328	Health Economics	12
90-832	Health Law	6
90-433	Population Health	6
88-365/90-882	Behavioral Economics and Public Policy	9
Other courses as approved		

Health Analytics & IT Focus		Units
94-409	Healthcare Information Systems	12
90-834	Health Care Geographical Information Systems	12
42-444	Medical Devices	9
Other courses as approved		

Minor in Scientific Computing

Dr. Maggie Braun, Advisor, *MCS Dean's Office*
mabraun@andrew.cmu.edu

Sometimes called “computational science,” scientific computing is the application of high-performance computers and modern computational technologies to problems in the sciences and engineering. Research in this area is inherently multidisciplinary, requiring strong ties with a scientific discipline.

MCS students can easily build on their scientific training with this applied computational program. The curriculum consists of five areas of concentration, which span the natural sciences, mathematics, programming, and research. The curriculum is structured to allow flexibility in choosing courses that meet students’ particular interests or best compliment their major. The minor is also a natural choice for students majoring in any technical area.

Required Courses

Students must meet the requirements of the following categories:

A. Non-Introductory Science Requirement (9-12 units)
Complete 1 course from Biological Sciences, Chemistry, or Physics at the 200 level or higher, excluding those courses listed below as part of the requirements of the minor. Courses with a significant science component from other colleges may be substituted with approval from the minor advisor.

B. Computational Science Requirement (18-24 units)
Complete 2 of the following courses:

03-511	Computational Molecular Biology and Genomics	9
09-560	Computational Chemistry	12
15-386	Neural Computation	9
33-241	Introduction to Computational Physics	9

C. Computational Methods Requirement (9 units)
Complete one of the following courses from outside of your home department.

21-369	Numerical Methods	12
33-658	Quantum Computation and Quantum Information Theory	10
33-232	Mathematical Methods of Physics	10
33-456	Advanced Computational Physics	9
36-410	Introduction to Probability Modeling	9

D. Applied Scientific Computing Research Project(s) (9 units)
Complete one approved research project in an area of applied scientific computing. In some cases, this research could be replaced with 9 units of an approved project-based course in advanced scientific computing. The administrator of the minor will maintain a list of appropriate courses. Under special circumstances summer research may count toward this requirement, although it cannot be counted toward the units required for graduation.

E. Complete any additional course from category C or D (9 units)

School of Computer Science

Martial Hebert, Dean

Thomas Cortina, Associate Dean for Undergraduate Programs

Veronica Peet, Assistant Dean for Undergraduate Experience

Location: GHC 4115
www.cs.cmu.edu/undergraduate-programs (http://www.cs.cmu.edu/undergraduate-programs/)

Carnegie Mellon founded one of the first Computer Science departments in the world in 1965. As research and teaching in computing grew at a tremendous pace at Carnegie Mellon, the university formed the School of Computer Science (SCS) at the end of 1988. Carnegie Mellon was one of the first universities to elevate Computer Science into its own academic college at the same level as the Mellon College of Science and the College of Engineering. Today, SCS consists of seven departments and institutes, including the Computer Science Department that started it all, along with the Ray and Stephanie Lane Computational Biology Department, the Human-Computer Interaction Institute, the Language Technologies Institute, the Machine Learning Department, the Robotics Institute and the Software and Societal Systems Department (formerly the Institute for Software Research). Together, these units make SCS a world leader in research and education. Over the last seven years, SCS has launched four new primary undergraduate majors in Computational Biology, Artificial Intelligence (the first of its kind in the United States), Human-Computer Interaction, and Robotics. These new majors, along with the highly-ranked Computer Science major, give students in SCS distinct paths in the field of computing with ample opportunities in industry and advanced research.

The School of Computer Science offers the following majors and minors:

- B.S. in Artificial Intelligence
- B.S. in Computational Biology
- B.S. in Computer Science
- B.S. in Human-Computer Interaction
- B.S. in Robotics
- Bachelor's in Computer Science and Art (joint with the College of Fine Arts)
- Additional major in Artificial Intelligence
- Additional major in Computational Biology
- Additional major in Computer Science
- Additional major in Human-Computer Interaction (Interdisciplinary)
- Additional major in Robotics
- Minor in Artificial Intelligence
- Minor in Computational Biology
- Minor in Computer Science
- Minor in Human-Computer Interaction
- Minor in Information Security, Privacy and Policy
- Minor in Language Technologies
- Minor in Machine Learning
- Minor in Neural Computation
- Minor in Robotics
- Minor in Software Engineering

Information for these majors and minors can be found through the navigation menu or through the links below:

- Artificial Intelligence (p. 674) (B.S. degree, additional major, minor)
- Computational Biology (p. 679) (B.S. degree, additional major, minor)
- Computer Science (p. 683) (B.S. degree, additional major, minor)
- Human-Computer Interaction (p. 688) (B.S. degree, additional interdisciplinary major, minor)
- Robotics (http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/robotics/) (B.S. degree, additional major, minor)
- SCS additional majors and minors (p. 700)

Students who apply to, and are directly admitted into, the School of Computer Science can choose between five primary majors: Artificial Intelligence, Computational Biology, Computer Science, Human-Computer Interaction and Robotics. Students with artistic and computing interests may be given the option to pursue a major in Computer Science and Art. Suitably prepared students from other Carnegie Mellon colleges are eligible to apply for internal transfer to the School of Computer Science and will be considered for transfer if grades in specific requirements are sufficiently high and space is available. Consult the program websites for specific requirements for transfer requests. Computation-oriented programs are also available within the Mellon College of Science, the Dietrich College of Humanities and Social Sciences, the College of Engineering and the College of Fine Arts.

Policies & Procedures

Academic Standards and Actions

Grading Practices

Grades given to record academic performance in SCS are detailed under Grading Practices at Undergraduate Academic Regulations (p. 25).

Dean's List WITH HIGH HONORS

SCS recognizes each semester those undergraduates who have earned outstanding academic records by naming them to the Dean's List with High Honors. The criterion for such recognition is a semester quality point average of at least 3.75 while completing a minimum of 36 factorable units and earning no incomplete grades.

Academic Actions

To maintain good academic standing, students from SCS must attain a quality point average (QPA) of at least 2.0 for each semester and a cumulative QPA of 2.0 and maintain adequate progress toward completing their degree requirements. For students with incomplete grade(s), default grade(s) will be used in the QPA calculation. For SCS, adequate progress toward completing degree requirements includes passing foundational courses of 15-112, 15-122, 15-151 (or 21-127 if applicable), 21-120 and 21-122 with grades of C or higher by the end of the sophomore year. A review of a student’s academic record is completed after each Fall and Spring semester.

A student will no longer be in good standing if they meet any of the following criteria:

- Their semester QPA is below 2.00.
- Their cumulative QPA is below 2.00.
- They fail to complete a required foundational CS or math course after two or more attempts with a C or higher. These courses include: 15-112, 15-122, 15-151 (or 21-127), 21-120, 21-122.
- They do not complete their required foundational CS and math requirements by the end of the sophomore year.

Students who are not in good standing are first put on Academic Warning for the following semester. After that following semester, if the student is still not in good standing, the student will be put on Academic Suspension. However, a student on Academic Warning who is meeting the semester QPA requirement but is not yet meeting other requirements may be continued on Academic Warning. If the QPA is impacted by an incomplete grade, the action will be reviewed once the final grade is posted, and the action will be rescinded if appropriate.

A student is removed from Academic Warning and returned to good academic standing when both the semester and cumulative quality point averages are at least 2.0, and if adequate progress toward completing degree requirements is being made (i.e. completing foundational courses).

The minimum period of Academic Suspension is one academic year (two non-summer semesters). Academic suspension is meant to allow a student to take a pause from their academic studies to address the issues that are causing poor academic performance. At the end of that period a student may return to campus (on Final Academic Warning) by:

1. completing a Return from Leave form from the HUB and submitting this form to their academic advisor, and
2. submitting an additional written statement to their academic advisor and the SCS Associate Dean for Undergraduate Programs, minimum one page, that outlines what the student did while on leave to address

the issues that led to the suspension and that would indicate future success on return, and

3. (optional) submitting up to two letters of support from individuals supporting the student's return to the academic advisor and the SCS Associate Dean for Undergraduate Programs.

Upon review by the student's academic advisor and the Associate Dean for Undergraduate Programs, in consultation with the Office of Student Affairs and the Office of International Education as appropriate, the student may be approved to continue their studies.

SCS students who return from Academic Suspension will be placed on Final Academic Warning for up to 2 semesters to allow them to return to good academic standing or transfer to another major that is more suitable to their interests and abilities. Students who return to good standing after a return from suspension will be removed from Final Academic Warning. Students who return to good standing after suspension but then do not meet one or more conditions as outlined above will return to Final Academic Warning.

Students who fail to return to good academic standing after two semesters on Final Academic Warning will be dropped from the School of Computer Science. Students who have been dropped and are not admitted to another program at the university are required to absent themselves from the campus (including residence halls and Greek houses) within a maximum of two days after the action.

Students may appeal an academic warning, suspension or drop decision in writing within 10 business days of notification. Students should consult with their academic advisor before appealing, and should typically only appeal if they believe that an academic action was not correctly determined by the above criteria or if they have substantial additional information which was not available when the academic action was decided and which indicates a timely return to good academic standing. Instructions on the appeal process are given in the warning, suspension or drop letter that is sent to the student.

Leave of Absence and Return from Leave of Absence

SCS undergraduate students may elect to take a leave of absence for a variety of reasons, after consultation with their academic advisor. Students who wish to take a leave of absence must do so by the last day of classes before final exams begin and before final grades are posted (in case this is earlier). Students requesting a leave of absence must complete a form from the HUB and have this signed by their academic advisor and SCS Associate Dean for Undergraduate Programs. Students who take a leave of absence up to the last day to drop classes will have all of their classes dropped. Students who take a leave of absence after the last day to drop classes will be assigned a grade of W (withdrawal) for all of their classes.

Students returning from a leave of absence are required to submit a Return from Leave of Absence form to their academic advisor for approval by the student's academic advisor and the SCS Associate Dean for Undergraduate Programs. In addition, for students taking a leave for academic performance reasons, the student must also supply a letter that explains the reason for the leave, the actions that were performed during the leave to prepare the student for a successful return, and a description of the on-campus resources, if required, that would be used by the student in order to increase the likelihood of success. Students returning from a leave are also encouraged to provide up to two letters of support from people close to the student (e.g. family, friends, clergy, teachers, coaches, others as appropriate). Requests to return are reviewed by the student's academic advisor, the Associate Dean and the Student Affairs liaison to determine eligibility and any resources that need to be put into place to assist the student upon return. Contact the SCS Undergraduate Office (GHC 4115) for more information.

Internal Transfer within SCS

First year students admitted to SCS are considered undeclared during their first year. These students declare their SCS major in the middle of the second semester of their first year of study. SCS students who wish to transfer from one SCS major to another SCS major may do so by applying for transfer by mid-semester break during the semester the transfer is desired (or the end of the summer session for summer transfers). These students should consult with their academic advisor and the program director of the intended major for more information about specific course requirements and academic plans. Internal SCS transfers do not have any grade requirements. Transfers are approved based on demonstrated interest, ability, and available space in the intended major. Consult the website for the individual SCS major for more information about expected courses to take to demonstrate interest and ability. The transfer request form is available on the SCS website.

Transfer into SCS / Dual-Degree

Undergraduate students admitted to colleges at CMU other than SCS and wishing to transfer to SCS or pursue a dual degree in SCS should consult with the Director or Program Coordinator of the desired SCS major during their first year. See the individual program pages for the names of the current directors and program coordinators, along with their contact information.

- For the Artificial Intelligence primary major, students must complete 15-122, 15-150, 15-281, 10-315, one of 15-210, 15-213 or 15-251, and one of 36-225, 21-325, 36-218 or 15-259, with an expected overall QPA over these six courses of 3.6 or higher.and an overall QPA of at least 3.0, in order to be considered for transfer or dual degree.
- For the Computational Biology primary major, students must complete 21-127 (or equivalent), 15-122, 15-251, 15-351 (or 15-210*), 03-121 and either 02-251 or 02-250 with an expected overall QPA over these six courses of 3.6 or higher and an overall QPA of at least 3.0, in order to be considered for transfer or dual degree. (*Students who take 15-210 will need to also take 15-150; this course is not required for the B.S. in Computational Biology but can count as an elective.)
- For the Computer Science primary major, students must complete 21-127 (or equivalent), 15-122, 15-150, 15-210, 15-213, 15-251 with an expected overall QPA over these six courses of 3.6 or higher and an overall QPA of at least 3.0, in order to be considered for transfer or dual degree.
- For the Human-Computer Interaction primary major, students must complete 21-127 (or equivalent), 15-122, 15-150, 05-410, one of 15-210 or 15-213, and one of 05-470 or 05-651, with an expected overall QPA over these six courses of 3.6 or higher and an overall QPA of at least 3.0, in order to be considered for transfer or dual degree.
- For the Robotics primary major, students must complete 21-127 (or equivalent), 15-122, 15-213, 15-251, one of the following robotics courses: 16-211, 16-299, 16-311 (or Robot Building when launched), and one of 36-225, 21-325, 36-218 or 15-259, with an expected overall QPA over these 6 courses of 3.6 or higher and an overall QPA of at least 3.0, in order to be considered for transfer or dual degree.

Students may apply for transfer by the start of the mid-semester break in the semester when the final course(s) of the six required courses will be completed (or the end of the summer session for summer transfer requests). In the case of course(s) in progress, the mid-semester grades will be used in the QPA calculation. The decision to allow transfer or dual degree will be made by committee based on the student's academic performance (in the specified courses and in their courses overall if necessary), additional involvement in SCS and other computing-related activities, and availability of space in the student's class level. Students should consult the SCS Undergraduate Office for complete information concerning minimum requirements, instructions and deadlines.

External Transfer

A student currently enrolled at another university or college who wishes to transfer to SCS should first apply through the Office of Admission. If the Office of Admission believes the applicant meets admission guidelines, the student's record is sent to SCS for evaluation. Admission is based on seat availability, overall academic performance and course rigor from the student's current institution, ability to complete the rigorous SCS program on time, and the application material including recommendations and reflection essay(s). It is important to note that extremely few external transfers are admitted to the SCS program at Carnegie Mellon University due to space limitations.

Graduation Requirements

1. A requirement for graduation is the completion of the program specified for a degree with a cumulative quality point average of 2.00 or higher for all courses taken at CMU.
2. Students must be recommended for a degree by the faculty of SCS.

3. A candidate for the bachelor's degree must complete at the University a minimum of four semesters of full-time study, or the equivalent of part-time study, comprising at least 180 units of course work.
4. Students will be required to have met all financial obligations to the university before being awarded a degree.

General Education Requirements

All undergraduate degrees in the School of Computer Science include depth in their particular field of study but also breadth through the general education requirements. General education requirements are part of SCS degrees to give students an opportunity to learn more about the world from scientific and humanistic points of view. These additional skills are useful for graduates since computing is often embedded in domains that are not entirely within the bounds of computing. SCS students will need to use their computing skills to solve problems alongside scientists and engineers, artists, social and cognitive scientists, historians, linguists, economists and business experts, and SCS students will need to communicate effectively and understand the ethical implications of their work. The general education requirements help SCS students gain this broad perspective so they can work well in a wide variety of domains.

Science and Engineering

All candidates for a B.S. degree in the School of Computer Science must complete a minimum of 36 units offered by the Mellon College of Science and/or the College of Engineering (CIT). This includes at least four courses in science and engineering, 9 units or more for each course, where at least one course must have a laboratory component and at least two courses must be from the same department. Consult with your SCS undergraduate advisor for possible use of any mini course for this requirement which needs to be reviewed by your advisor and the SCS Associate Dean for Undergraduate Programs.

For Computational Biology majors, consult the Computational Biology (p. 679) program page for specific science and engineering requirements. The required science and engineering courses for the Computational Biology major also satisfy the General Education requirement for SCS by default. For other SCS majors, consult the lists given below for approved courses.

Non-lab courses that satisfy this requirement are given in the list below. (Consult your academic advisor for additional choices available each semester.)

03-121	Modern Biology	9
or 03-151	Honors Modern Biology	
03-125	Evolution	9
03-132	Basic Science to Modern Medicine	9
03-133	Neurobiology of Disease	9
03-135	Structure and Function of the Human Body	9
03-140	Ecology and Environmental Science	9
03-161	Molecules to Mind	9
06-100	Introduction to Chemical Engineering	12
06-223	Chemical Engineering Thermodynamics	12
06-261	Fluid Mechanics	9
09-105	Introduction to Modern Chemistry I	10
09-106	Modern Chemistry II	10
09-217	Organic Chemistry I	9
09-218	Organic Chemistry II	9
09-225	Climate Change: Chemistry, Physics and Planetary Science	9
09-348	Inorganic Chemistry	10
12-100	Exploring CEE: Infrastructure and Environment in a Changing World	12
12-201	Geology	9
12-212	Statics	9
12-231	Solid Mechanics	9
12-351	Environmental Engineering	9
18-095	Getting Started in Electronics: An Experiential Approach	9
18-100	Introduction to Electrical and Computer Engineering	12
18-220	Electronic Devices and Analog Circuits	12
18-240	Structure and Design of Digital Systems	12
24-101	Fundamentals of Mechanical Engineering	12
24-221	Thermodynamics	10
24-231	Fluid Mechanics	10
24-292	Renewable Energy Engineering	9
24-358	Culinary Mechanics	9
24-381	Environmental Systems on a Changing Planet	12
27-215	Thermodynamics of Materials	12
33-114	Physics of Musical Sound	9
33-120	Science and Science Fiction	9
33-121	Physics I for Science Students	12
or 33-141	Physics I for Engineering Students	
or 33-151	Matter and Interactions I	
33-142	Physics II for Engineering and Physics Students	12
or 33-152	Matter and Interactions II	
33-211	Physics III: Modern Essentials	10
33-224	Stars, Galaxies and the Universe	9
33-225	Quantum Physics and Structure of Matter	9
33-226	Physics of Energy	9
42-101	Introduction to Biomedical Engineering (can be paired with a course in Biology 03-xxx for two courses in one department)	12
42-202	Physiology (can be paired with a course in Biology 03-xxx for two courses in one department)	9
85-219	Foundations of Brain and Behavior (can be paired with a course in Biology 03-xxx for two courses in one department)	9

At present, courses meeting the lab requirement include:

02-261	Quantitative Cell and Molecular Biology Laboratory (can be paired with a course in Biology 03-xxx for two courses in one department)	9
02-262	Computation and Biology Integrated Research Lab (can be paired with a course in Biology 03-xxx for two courses in one department)	Var.
03-124	Modern Biology Laboratory	9
09-101	Introduction to Experimental Chemistry (This 3 unit lab together with 09-105 satisfies the lab requirement.)	3
09-221	Laboratory I: Introduction to Chemical Analysis	12
27-100	Engineering the Materials of the Future	12
33-104	Experimental Physics	9
33-228	Electronics I	10
42-203	Biomedical Engineering Laboratory	9
85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9

The following MCS and CIT courses cannot be used to satisfy the Science and Engineering requirement (see note below this list for additional exceptions and conditions):

03-511	Computational Molecular Biology and Genomics	9
04-330	Fundamentals of Software Development and Problem Solving	12
06-262	Mathematical Methods of Chemical Engineering	12
09-103	Atoms, Molecules and Chemical Change	9
09-108	The Illusion and Magic of Food	6
09-109	Kitchen Chemistry Sessions	3
09-110	The Design and Making of Skin and Hair Products	3
09-114	Basics of Food Science	3
09-204	Professional Communication Skills in Chemistry	3
09-209	Kitchen Chemistry Sessions	3
09-231	Mathematical Methods for Chemists	9
12-215	Introduction to Professional Writing in CEE	9
12-271	Computation and Data Science for Civil & Environmental Engineering	9
18-090	Twisted Signals: Multimedia Processing for the Arts	10
18-200	ECE Sophomore Seminar	1
18-202	Mathematical Foundations of Electrical Engineering	12
18-213	Introduction to Computer Systems	12
18-330	Introduction to Computer Security	12
18-334	Network Security	12

18-335	Secure Software Systems	12
18-411	Computational Techniques for Data Science and Engineering	12
18-441	Computer Networks	12
18-460	Optimization	12
18-461	Introduction to Machine Learning for Engineers	12
18-462	Principles and Engineering Applications of AI	12
18-465	Advanced Probability & Statistics for Engineers	12
18-482	Telecommunications Technology and Policy for the Internet Age	12
18-487	Introduction to Computer Security	12
18-540	Rapid Prototyping of Computer Systems	12
19-101	Introduction to Engineering and Public Policy	12
19-211	Ethics and Policy Issues in Computing (or 17-200)	9
19-213	The American Railroad: Decline and Renaissance in the Age of Deregulation	6
19-301	Decision Making Methods for Engineers and Scientists	9
19-303	Cryptocurrencies, Blockchains and Applications	9
19-351	Applied Methods for Technology-Policy Analysis	9
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-403	Policies of Wireless Systems	12
19-411	Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech	9
19-421	Emerging Energy Policies	9
19-425	Sustainable Energy for the Developing World	9
19-433	Data Science for Technology, Innovation and Policy	9
19-534	Usable Privacy and Security	9
19-608	Privacy Policy, Law, and Technology	12
24-281	Introduction to Scientific Computing	2
24-311	Numerical Methods	10
27-410	Computational Techniques in Engineering	12
33-100	Basic Experimental Physics	6
33-115	Physics for Future Presidents	9
33-124	Introduction to Astronomy	9
33-232	Mathematical Methods of Physics	10
42-201	Professional Issues in Biomedical Engineering	3
49-300	Integrated Product Conceptualization	12

All Electrical and Computer Engineering graduate courses [18-6xx, 18-7xx, 18-8xx, 18-9xx] cannot be used for this requirement. Students interested in Engineering & Public Policy (19-xxx) courses that are not excluded above, including special topics courses, must consult with their SCS undergraduate advisor and the SCS Associate Dean for Undergraduate Programs to determine suitability for this requirement. In general, any MCS or CIT courses that are cross-listed with SCS courses or have significant mathematical or computational content **cannot** be used for this requirement. Students must consult with an SCS undergraduate advisor about any course to be used for the Science and Engineering requirement before registration.

Humanities and Arts

All candidates for a B.S. degree in the School of Computer Science must complete a minimum of 63 units offered by the College of Humanities & Social Sciences and/or the College of Fine Arts as prescribed below. Students pursuing a Bachelor's in Computer Science and Art (p.) should consult the general education requirements for that program.

A. Freshman Writing Requirement (9 units)

Complete one of the following writing options for 9 units:		
76-101	Interpretation and Argument	9
76-102	Advanced First Year Writing: Special Topics (by invitation only)	9
or two of these three writing minis for 9 units total:		
76-106	Writing about Literature, Art and Culture	4.5
76-107	Writing about Data	4.5
76-108	Writing about Public Problems	4.5

B. Breadth Requirement (minimum 27 units: 9 units each)

Complete three courses, one each from Category 1, Category 2, and Category 3. Students may use two minis totaling 9 units or more to satisfy one of the categories, with permission of the Associate Dean for Undergraduate Education, if the minis meet the goals of the desired category. **NOTE: Artificial Intelligence majors replace Category 1 with Category 1A: Cognitive Studies which is a subset of Category 1.**

Category 1 (for all SCS majors except Artificial Intelligence): Cognition, Choice and Behavior - this requirement explores the process of thinking, decision making, and behavior in the context of the individual.		
70-311	Organizational Behavior	9
70-318	Managing Effective Work Teams	9
70-385	Consumer Behavior	9
80-101	Dangerous Ideas in Science and Society	9
80-130	Introduction to Ethics	9
80-150	Nature of Reason	9
80-180	Nature of Language: An Introduction to Linguistics	9
80-221	Philosophy of Social Science	9
80-252	Kant	9
80-270	Problems of Mind and Body: Meaning and Doing	9
80-271	Mind and Body: The Objective and the Subjective	9
80-275	Metaphysics	9
80-330	Ethical Theory	9
85-102	Introduction to Psychology	9
85-104	Psychopathology	9
85-211	Cognitive Psychology	9
85-213	Human Information Processing and Artificial Intelligence	9
85-221	Principles of Child Development	9
85-241	Social Psychology	9
85-251	Personality	9
85-261	Psychopathology	9
85-370	Perception	9
85-408	Visual Cognition	9
85-414	Cognitive Neuropsychology	9
85-421	Language and Thought	9
88-120	Reason, Passion and Cognition	9
88-230	Human Intelligence and Human Stupidity	9
88-231	Thinking in Person vs. Thinking Online	9

Category 1A (for Artificial Intelligence majors): Cognitive Studies - this requirement explores how the brain and the mind work.		
85-211	Cognitive Psychology	9
85-213	Human Information Processing and Artificial Intelligence	9
85-370	Perception	9
85-408	Visual Cognition	9
85-421	Language and Thought	9

Category 2 (all SCS majors): Economic, Political and Social Institutions - this requirement explores the processes by which institutions organize individual preferences and actions into collective outcomes.		
19-101	Introduction to Engineering and Public Policy	12
36-303	Sampling, Survey and Society	9
66-221	Topics of Law: Introduction to Intellectual Property Law	9
70-332	Business, Society and Ethics	9
73-102	Principles of Microeconomics	9
73-103	Principles of Macroeconomics	9
73-104	Principles of Microeconomics Accelerated	9
76-425	Rhetoric, Science, and the Public Sphere	9
79-101	Making History: How to Think About the Past (and Present)	9
79-189	Democracy and History: Thinking Beyond the Self	9
79-237	Comparative Slavery	9
79-244	Women in American History	9
79-253	Imperialism and Decolonization in South Asia	9
79-300	Controversial Topics in the History of American Public Policy	9

79-320	Women, Politics, and Protest	9
79-321	Documenting Human Rights	9
79-331	Body Politics: Women and Health in America	9
79-370	Technology in the United States	9
79-383	The History of Capitalism	9
79-391	Nations and Nationalisms in South Asia	9
79-392	Europe and the Islamic World	9
80-135	Introduction to Political Philosophy	9
80-136	Social Structure, Public Policy & Ethics	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-324	Philosophy of Economics	9
80-335	Social and Political Philosophy	9
80-334	Social and Political Philosophy	9
80-348	Health, Human Rights, and International Development	9
84-104	Decision Processes in American Political Institutions	9
84-110	The Economics of Politics, Policy, and Technology	9
84-275	Comparative Politics	9
84-322	Nonviolent Conflict and Revolution	9
84-324	The Future of Democracy	9
84-352	Representation and Voting Rights	9
84-362	Diplomacy and Statecraft	9
84-365	The Politics of Fake News and Misinformation	9
84-380	US Grand Strategy	9
84-386	The Privatization of Force	9
84-387	Remote Systems and the Cyber Domain in Conflict	9
84-389	Terrorism and Insurgency	9
84-390	Social Media, Technology, and Conflict	9
84-393	Legislative Decision Making: US Congress	9
84-402	Judicial Politics and Behavior	9
84-405	The Future of Warfare	9
88-281	Topics in Law: 1st Amendment	9
88-284	Topics of Law: The Bill of Rights	9

Category 3 (all SCS majors): Cultural Analysis - this requirement seeks to recognize cultures that have shaped and continue to shape the human experience; courses in this category are usually either broad in place, time, or cultural diversity.

48-240	History of World Architecture, I	9
48-241	History of Modern Architecture	9
57-173	Survey of Western Music History	9
60-105	Cultural History of the Visual Arts	9
60-106	Cultural History of the Visual Arts - the Modern Period	9
62-371	Photography, The First 100 Years, 1839-1939	9
70-342	Managing Across Cultures	9
70-348	Cross-Cultural Business Communications	9
76-221	Books You Should Have Read By Now	9
76-230	Literature & Culture in the 19th Century	9
76-232	Introduction to Black Literature	9
76-239	Introduction to Film Studies	9
76-241	Introduction to Gender Studies	9
76-339	Topics in Film and Media	9
76-386	Language & Culture	9
79-104	Global Histories	9
79-145	Genocide and Weapons of Mass Destruction	9
79-201	Introduction to Anthropology	9
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-226	African History: Earliest Times to 1780	9
79-229	The Origins of the Palestinian-Israeli Conflict, 1880-1948	9
79-230	The Arab-Israeli Conflict and Peace Process Through 1948 to Present	9
79-234	Technology and Society	9
79-240	Development of American Culture	9
79-242	African American History: Reconstruction to the Present	9
79-245	Capitalism and Individualism in American Culture	9
79-248	U.S. Constitution & the Presidency	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-265	Russian History: Game of Thrones	9
79-281	Introduction to Religion	9
79-282	Europe and the World Since 1800	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-293	Inward Odyssey	9
79-316	Photography, the First 100 Years, 1839-1939	9
79-329	LGBTQ+ History	9
79-345	Roots of Rock & Roll	9
79-350	Early Christianity	9
79-378	Gender in South Asia	9
79-393	Institutions of the Roman Church	9
79-395	The Arts in Pittsburgh	9
79-396	Music, Art, and Society in 19th and 20th Century Europe and the U.S.	9
79-465	The Arts in Qatar	9
80-100	Introduction to Philosophy	9
80-250	Ancient Philosophy	9
80-251	Modern Philosophy	9
80-253	Continental Philosophy	9
80-254	Analytic Philosophy	9
80-255	Pragmatism: Making Ideas Work	9
80-261	Experience, Reason, and Truth	9
80-276	Philosophy of Religion	9
82-119	Arabic Calligraphy Culture & Skills	9
82-267	Beyond the Mafia and Michelangelo	9
82-273	Introduction to Japanese Language and Culture	9
82-279	Anime - Visual Interplay between Japan and the World	9
82-280	Billingual & Bicultural Experiences in the US	9
82-282	Interpreting Global Texts & Cultures	9
82-283	Language Diversity & Cultural Identity	9
82-286	Of Minorities and Migrants: Exploring Germany from the Margins Germany Today	9
82-293	Russian Cinema: From the Bolshevik Revolution to Putin's Russia	9
82-294	19th Century Russian Masterpieces	9
82-303	French & Francophone Cultures	9
82-304	French & Francophone Sociolinguistics	9
82-313	Topics in Modern Arabic Language, Literature and Culture	9
82-314	Literature of the Arabic-speaking World	9
82-327	The Emergence of the German Speaking World	9
82-333	Introduction to Chinese Language and Culture	9
82-342	Spain: Language and Culture	9
82-343	Latin America Language and Culture	9
82-344	U.S. Latine Cultures	9
82-345	Using Spanish in Social Contexts	9
82-436	Introduction to Classical Chinese	9

C. Humanities and Arts Electives (minimum 27 units)
Complete 3 non-technical courses of at least 9 units each from any of the departments in the Dietrich College of Humanities & Social Sciences or the College of Fine Arts. Some of the courses taught in these units are considered technical courses and may not be used to satisfy this requirement (see Deletions below). Additionally, a select set of courses from Business Administration and from Environmental and Public Policy can also count for this requirement (see Additions below). Students may combine humanities/arts courses with lower units together to form a single course of 9 units or more with advisor approval in consultation with the SCS Associate Dean for Undergraduate Programs. Students are encouraged, but not required, to take courses from different departments to gain additional

breadth and to create new opportunities for engagement with the university community.

Deletions

Some courses from the Dietrich College or the College of Fine Arts may not count toward the unconstrained electives in Humanities and Arts in SCS due to the technical (computing and/or mathematical) nature of the courses. Courses from the following departments do not count toward the unconstrained Humanities and Arts electives:

- Statistics and Data Science (36), except 36-303 Sampling, Survey and Society
- Information Systems (67)
- Economics (73), except 73-102 Principles of Microeconomics, 73-103 Principles of Macroeconomics, 73-104 Principles of Microeconomics Accelerated, and 73-369 Islamic Economics.

Additionally, the following courses do NOT count toward the unconstrained Humanities and Arts electives:

51-257	Introduction to Computing for Creative Practices	10
51-327	Design Center: Introduction to Web Design	9
51-328	Design Center: Design for Digital Systems	9
76-388	Coding for Humanists	9
76-481	Introduction to Multimedia Design	12
76-487	Information Architecture & Content Strategy	9
80-210	Logic and Proofs	9
80-211	Logic and Mathematical Inquiry	9
80-212	Arguments and Logical Analysis	9
80-305	Game Theory	9
80-306	Decision Theory	9
80-310	Formal Logic	9
80-311	Undecidability and Incompleteness	9
80-315	Logics for Knowledge and Belief	9
80-316	Logic and AI	9
80-325	Foundations of Causation and Machine Learning	9
80-411	Proof Theory	9
80-413	Category Theory	9
80-419	Interactive Theorem Proving	9
80-514	Categorical Logic	9
80-521	Seminar on Formal Epistemology: Belief and Evidence	Var.
85-219	Foundations of Brain and Behavior	9
85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9
85-414	Cognitive Neuropsychology	9
85-426	Learning in Humans and Machines	9
88-251	Empirical Research Methods	9
88-372	Social and Emotional Brain	9

Additions

The following courses outside of Dietrich College and the College of Fine Arts may count toward the unconstrained Humanities and Arts electives:

07-135	Grand Challenge First-Year Seminar: Designing Better Human-AI Futures	9
11-423	ConLanging: Lrng. Ling. & Lang Tech via Constru Artif. Lang.	12
16-161	ROB Seminar: Artificial Intelligence and Humanity	12
16-397	Art, Conflict and Technology	12
17-333	Privacy Policy, Law, and Technology	9
17-562	Law of Computer Technology	9
19-101	Introduction to Engineering and Public Policy	12
19-351	Applied Methods for Technology-Policy Analysis	9
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-403	Policies of Wireless Systems	12
19-411	Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech	9
21-150	Mathematics and the Arts	9
32-201	Leadership & Management	9
32-402	Leadership and Ethics	9
70-100	Global Business	9
70-311	Organizational Behavior	9
70-318	Managing Effective Work Teams	9
70-321	Negotiation and Conflict Resolution	9
70-332	Business, Society and Ethics	9
70-340	Business Communications	9
70-341	Team Dynamics and Leadership	9
70-342	Managing Across Cultures	9
70-345	Business Presentations	9
70-348	Cross-Cultural Business Communications	9
70-350	Acting for Business	9
70-352	Business Acting	3
70-364	Business Law	6
70-365	International Trade and International Law	9
70-381	Marketing I	9
70-430	International Management	9
70-443	Digital Marketing and Social Media Strategy	9

Honors Research Thesis

Students considering going on to graduate school in Computer Science or related disciplines should take a wide variety of Computer Science and Mathematics courses, as well as consider getting involved in independent research as early as possible. This would be no later than the junior year and can begin even earlier. Students interested in graduate school in computer science or its related areas are strongly encouraged to participate in the SCS Honors Undergraduate Research Thesis program. Additionally, graduate CS courses can be taken with permission of the instructor and in consultation with an academic advisor.

The goal of the SCS Honors Undergraduate Research Thesis Program is to introduce students to the breadth of tasks involved in independent research, including library work, problem formulation, experimentation, analysis, technical writing and public speaking. In particular, students write a short paper summarizing prior results and current progress in their desired area of research, present a public poster session in December of their senior year describing their current progress, present their final results with a poster and an oral presentation in the year-end university-wide Undergraduate Research Symposium (Meeting of the Minds) and submit a written thesis at the end of their senior year. Students work closely with faculty research advisors to plan and carry out their research. The 07-599 SCS Honors Undergraduate Research Thesis typically starts in the fall semester of the senior year, and spans the entire senior year. Students receive a total of 36 units of academic credit for the thesis work, 18 units per semester. Students should prepare their research prospectus (i.e. proposal of work) during the spring semester of their junior year, and students in this program are advised to plan their schedules carefully to ensure there is ample time to perform the required research for the thesis during the senior year.

Students interested in research are urged to consult with their undergraduate advisor and the SCS Associate Dean for Undergraduate Programs no later than the end of their sophomore year in order to plan their workload effectively. Although there is no specific QPA requirement to participate, students are expected to have at least a 3.5 QPA in the core SCS topics relevant to their proposed research to be successful in their work. For those students with no background in research, they may consider using 07-300 Research and Innovation in Computer Science (9 units) as an introduction to the research process in their junior year since this course will introduce students to various research projects going on in the School of Computer Science and important skills that are needed to be an effective researcher. This course leads to a subsequent research practicum, 07-400 Research Practicum in Computer Science (12 units), that allows students to complete a small-scale research study or experiment and present a research poster. Students who use this practicum to start their senior thesis can use the 12 units toward the required 36 units. Students should consult with their academic advisor concerning how the units earned toward the senior thesis can be used toward elective requirements for their major.

Interested juniors should submit a project prospectus of 3-4 pages by the end of their junior year, although submissions over the summer prior to the senior year will also be considered for review. A prospectus must include:

- The name of the research advisor (an SCS faculty member)
- A short abstract (two paragraphs, max)
- A description of the problem to be worked on and its significance
- A tactical description of the proposed research plan, including:
    - a description of the background reading to be carried out,
    - a description of the research contribution,
    - a description of the expected results of the research, and
    - a reasonably detailed timeline for the thesis work
- A bibliography of related work (all references belong here)

- The signature of the research advisor, signifying endorsement of the project and willingness to supervise and evaluate it (or an email confirmation from the research advisor)

Students who need help finding potential advisors should get in touch with their academic advisor or the Associate Dean for Undergraduate Programs. Applications to the program are due by the start of the senior year, although submission of applications in the junior year is encouraged.

Students completing an outstanding senior thesis based on the judgement of the SCS Undergraduate Review Committee will earn SCS College Honors and can compete for various SCS research awards given out during commencement.

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TUOMAS SANDHOLM, Professor, Computer Science Department – Ph.D., University of Massachusetts; Carnegie Mellon, 2001–

MAARTEN SAP, Assistant Professor, Language Technologies Institute – Ph.D., University of Washington; Carnegie Mellon, 2022–

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RICHARD SCHEINES, Dean, Dietrich College and Professor, Philosophy – Ph.D., University of Pittsburgh; Carnegie Mellon, 1988–

SEBASTIAN SCHERER, Associate Research Professor, Robotics Institute – Ph.D, Carnegie Mellon University; Carnegie Mellon, 2010–

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GEORGE STETTEN, Adjunct Research Professor, Robotics Institute – Ph.D., University of North Carolina; Carnegie Mellon, 1999–

EMMA STRUBELL, Assistant Professor, Language Technologies Institute – Ph.D, University of Massachusetts, Amherst; Carnegie Mellon, 2020–

JOSHUA SUNSHINE, Systems Scientist, Institute for Software Research – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2014–

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YUN WILLIAM YU, Assistant Professor, Computational Biology Department – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2023–

MARTIN ZHANG, Assistant Professor, Computational Biology Department – Ph.D., Stanford University; Carnegie Mellon, 2023–

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Artificial Intelligence Program

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Kaleigh Mitchell, Program Administrator (GHC 4113)
www.cs.cmu.edu/bs-in-artificial-intelligence (http://www.cs.cmu.edu/bs-in-artificial-intelligence/)

Overview

Carnegie Mellon University has led the world in artificial intelligence education and innovation since the field was created. It's only natural, then, that the School of Computer Science would offer the nation's first bachelor's degree in Artificial Intelligence, which started in Fall 2018.

The BSAI program gives students the in-depth knowledge needed to transform large amounts of data into actionable decisions. The program and its curriculum focus on how complex inputs — such as vision, language and huge databases — can be used to make decisions or enhance human capabilities. The curriculum includes coursework in computer science, math, statistics, computational modeling, machine learning and symbolic computation. Because Carnegie Mellon is devoted to AI for social good, students will also take courses in ethics and social responsibility, with the option to participate in independent study projects that change the world for the better — in areas like healthcare, transportation and education.

Just as AI unites disciplines from machine learning to natural language processing, instruction in the BSAI program includes faculty members from the school's Computer Science Department, Human-Computer Interaction Institute, Institute for Software Research, Language Technologies Institute, Machine Learning Department and Robotics Institute.

Students in the BSAI program within the School of Computer Science are expected to acquire the following skills upon graduation:

- Understand how to distill a real-world challenge as an artificial intelligence problem, involving explicit representation and learning of symbolic and numeric models; reasoning about such models; and using such models for decision making, action selection, and interaction with humans.
- Design, analyze, implement, and use state-of-the-art AI and machine learning techniques for dealing with real-world data, including data involving vision, language, perception, and uncertainty.
- Master the core concepts of computer science, with emphasis on data structures, programming, computing systems, and algorithm design, performance, and correctness across a variety of metrics (e.g., time, space, parallel vs. sequential implementation, what is computable).
- Master the fundamentals of discrete mathematics, logic, theorem proving and explanation, probability and statistics, and optimization.
- Describe, specify, and develop large-scale, open-ended artificial intelligence systems subject constraints such as performance, available data, and need for transparency. Communicate technical material effectively to technical and non-technical audiences.
- Work productively both individually and in teams.
- Recognize the social impact of artificial intelligence and the underlying responsibility to consider the ethical, privacy, moral, and legal implications of artificial intelligence technologies.

Students who graduate with a bachelors degree in AI, will have the computer science savvy and skills our students are known for, with the added expertise in machine learning and automated reasoning that you'll need to build the AI of tomorrow.

How to Apply

If you're applying to CMU, you need to be accepted into the School of Computer Science. Once you're at CMU and enrolled in SCS, you can declare a BSAI major in the spring of your first year or transfer into the program in your sophomore or junior year. If you are already at CMU but not in SCS, you can apply to transfer into the program after your sophomore year. Consult with the director or the program administrator of the BSAI program for information.

Curriculum

BSAI majors will take core courses in math and statistics, computer science, artificial intelligence and ethics, along with general education courses in science and engineering, and humanities and arts.

Math and Statistics

All of the following:		Units
15-151	Mathematical Foundations for Computer Science (if not offered, substitute 21-127)	12
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-241	Matrices and Linear Transformations	11
21-259	Calculus in Three Dimensions or 21-266, or 21-268, or 21-269	10
Probability and Statistics (one of the following options):		
36-218	Probability Theory for Computer Scientists	9
15-259	Probability and Computing	12
21-325-36-226	Probability - Introduction to Statistical Inference	18
36-225-36-226	Introduction to Probability Theory - Introduction to Statistical Inference	18
36-235-36-236	Probability and Statistical Inference I-II	18
plus Modern Regression:		
36-401	Modern Regression	9

Computer Science

All of the following:		Units
15-122	Principles of Imperative Computation (students without credit or a waiver for 15-112, Fundamentals of Programming and Computer Science, must take 15-112 before 15-122)	12
15-150	Principles of Functional Programming	12
15-210	Parallel and Sequential Data Structures and Algorithms	12
15-213	Introduction to Computer Systems	12
15-251	Great Ideas in Theoretical Computer Science	12

Artificial Intelligence

All of the following AI core courses:		Units
15-281	Artificial Intelligence: Representation and Problem Solving	12
10-315	Introduction to Machine Learning (SCS Majors)	12
plus one of the following AI core courses:		
16-385	Computer Vision	12
11-411	Natural Language Processing	12

One Decision Making and Robotics course (min. 9 units):		Units
15-386	Neural Computation	9
15-482	Autonomous Agents	12
15-494	Cognitive Robotics: The Future of Robot Toys	12
16-350	Planning Techniques for Robotics	12
16-362	Mobile Robot Algorithms Laboratory	12
16-384	Robot Kinematics and Dynamics	12
others as designated by the AI Undergraduate Program		

One Machine Learning course from the following (min. 9 units):		
10-403	Deep Reinforcement Learning & Control	12
10-405	Machine Learning with Large Datasets (Undergraduate)	12
10-414	Deep Learning Systems: Algorithms and Implementation	12
10-417	Intermediate Deep Learning	12
10-418	Machine Learning for Structured Data	12
10-422	Foundations of Learning, Game Theory, and Their Connections	12

10-423	Generative AI	12
10-425	Introduction to Convex Optimization	12
11-441	Machine Learning with Graphs	9
11-485	Introduction to Deep Learning	9
36-402	Advanced Methods for Data Analysis	9
others as designated by the AI Undergraduate Program		

One Perception and Language course from the following (min. 9 units):		
11-442	Search Engines	9
11-492	Speech Technology for Conversational AI	12
15-387	Computational Perception	9
15-463	Computational Photography	12
16-421	Vision Sensors	12
others as designated by the AI Undergraduate Program		

One Human-AI Interaction course from the following (min. 12 units):		
05-317	Design of Artificial Intelligence Products	12
05-318	Human AI Interaction	12
05-391	Designing Human Centered Software	12
16-467	Introduction to Human Robot Interaction	12
others as designated by the AI Undergraduate Program		

School of Computer Science Electives

Two general computer science electives:	Units
These electives can be from any SCS department (Computational Biology [02-], Human-Computer Interaction [05-], Interdisciplinary [07-], Machine Learning [10-], Language Technologies [11-], Computer Science [15-], Robotics [16-], or Software & Societal Systems [17-]). They must be 200-level or above and at least 9 units each, with the following exceptions:	18
Students who take two of the major-intro mini-courses (02-180, 05-180, 07-180, or 16-180) during their first year may combine these two mini-courses together to count as one SCS elective;	
The following courses do NOT count as SCS electives: 02-201, 02-223, 02-250, 02-261, 05-200, 11-423, 15-351, 16-211, 16-223, 16-224, 16-397, 16-480, 17-200, 17-333, 17-562; Some IDEATE courses and some SCS undergraduate and graduate courses might not be allowed based on course content. Always consult with an AI undergraduate advisor before registration to determine eligibility for this requirement.	

Ethics Course

One of the following courses:		Units
16-161	ROB Seminar: Artificial Intelligence and Humanity	12
16-735	Ethics and Robotics	12
17-200	Ethics and Policy Issues in Computing	9
80-249	AI, Society, and Humanity	9

SCIENCE AND ENGINEERING

All candidates for the bachelor's degree in Artificial Intelligence must complete a minimum of 36 units offered by the Mellon College of Science (MCS) and/or the College of Engineering (CIT). These courses offer students an opportunity to explore scientific and engineering domains that can influence their effectiveness as computer scientists upon graduation.

Requirements for this component of the degree are listed under the SCS main page under General Education Requirements (p. 664).

Humanities and Arts

All candidates for the bachelor's degree in Artificial Intelligence must complete a minimum of 63 units offered by the College of Humanities & Social Sciences and/or the College of Fine Arts. These courses offer students breadth in their education and perspectives and provide students with a better appreciation of social, artistic, cultural, political and economic issues that can influence their effectiveness as computer scientists upon graduation.

Requirements for this component of the degree are listed under the SCS main page under General Education Requirements (p. 664). **SPECIAL NOTE FOR AI STUDENTS: AI majors must satisfy Category 1 of the General Education requirements by taking one of the following Cognitive Studies (Category 1A) courses:**

- 85-211 Cognitive Psychology
- 85-213 Human Information Processing and Artificial Intelligence
- 85-370 Perception
- 85-408 Visual Cognition
- 85-421 Language and Thought

SCS First year seminar

The following course is designed to acquaint incoming students with computer science at CMU:

07-128	First Year Immigration Course	3

CoRE@CMU

The following course is required of all CMU students:

99-101	Core@CMU	3

Free Electives

A free elective is any Carnegie Mellon course. However, a maximum of nine (9) units of Physical Education and/or Military Science (ROTC) and/or Student-Led (StuCo) courses may be used toward fulfilling graduation requirements.

Summary of Degree Requirements

Area	Courses	Units
Mathematics	7	**71**
Computer Science	5	**60**
Artificial Intelligence	7	**70**
SCS Electives	2	**18**
Ethics	1	**9**
Science/Engineering	4	**36**
Humanities/Arts (includes Cognitive Studies)	7	**63**
SCS First Year Seminar	1	**3**
Core@CMU	1	**3**
Free Electives	varies	**27**
		360

Undergraduate Research Thesis

AI majors may use the SCS Honors Research Thesis as part of their degree. The SCS Honors Undergraduate Research Thesis (07-599) typically starts in the fall semester of the senior year, and spans the entire senior year. Students receive a total of 36 units of academic credit for the thesis work, 18 units per semester. Up to 18 units can be counted toward SCS elective requirements (9 per semester for 2 semesters maximum). Students interested in research may also consider using 07-300 Research and Innovation in Computer Science in their junior year since this course will introduce students to various research projects going on in the School of Computer Science that may lead to a senior thesis. This course leads to a subsequent practicum that allows students to complete a small-scale research study or experiment and present a research poster. Students who use the practicum to start their senior thesis can use these units toward the required 36 units.

For more information about the SCS Honors Research Thesis, refer to the SCS Honors Research Thesis (p. 667) section for learning objectives, application requirements and expected outcomes.

BSAI Roadmap: Sample Course Sequence

The sample given below is for a student who already has credit for introductory programming and introductory calculus. Students with no credit for introductory programming will take 15-112 in their first semester and shift some CS courses to later semesters after consulting with their academic advisor; students with no credit for calculus will take 21-120 in their first semester and shift 21-122 and 21-259 to subsequent semesters. These students should still be able to complete their degree in four years given the light load of their senior year. Students with credit for 21-120 and 21-122 may start with a more advanced math class (e.g. 21-241) in their first year. It is recommended that students keep their academic load lighter for their senior fall semester to account for offsite job interviews or for their senior spring semester to account for visits to graduate schools.

FRESHMAN YEAR:

Fall		Units
07-128	First Year Immigration Course	3
15-122	Principles of Imperative Computation	12
15-151	Mathematical Foundations for Computer Science	12
21-122	Integration and Approximation	10
76-101	Interpretation and Argument	9
99-101	Core@CMU	3
		49

Spring		Units
xx-180	Two Major Introduction Minis (02-180, 05-180, 07-180, 16-180)	10
15-150	Principles of Functional Programming	12
15-213	Introduction to Computer Systems	12
21-241	Matrices and Linear Transformations	11
		45

SOPHOMORE YEAR:

Fall		Units
15-210	Parallel and Sequential Data Structures and Algorithms	12
15-281	Artificial Intelligence: Representation and Problem Solving	12
36-218	Probability Theory for Computer Scientists	9
xx-xxx	Science and Engineering Elective	9
xx-xxx	Ethics Elective	9
		51

Spring		Units
10-315	Introduction to Machine Learning (SCS Majors)	12
15-251	Great Ideas in Theoretical Computer Science	12
21-259	Calculus in Three Dimensions	10
85-xxx	Cognitive Studies Elective	9
xx-xxx	Humanities and Arts Elective	9
		52

JUNIOR YEAR:

Fall		Units
11-411	Natural Language Processing	12
or 16-385	Computer Vision	
36-401	Modern Regression	9
xx-xxx	AI Elective: Machine Learning	9
xx-xxx	Humanities and Arts elective	9
xx-xxx	Free Elective	9
		48

Spring		Units
xx-xxx	AI Elective: Human-AI Interaction	12
xx-xxx	AI Elective: Decision Making and Robotics	9
xx-xxx	Science and Engineering elective	9
xx-xxx	Humanities and Arts elective	9
xx-xxx	Free Elective	9
		48

SENIOR YEAR:

Fall		Units
xx-xxx	AI Elective: Perception and Language	9
xx-xxx	SCS Elective	9
xx-xxx	Science and Engineering Elective	9
xx-xxx	Humanities and Arts Elective	9
		36

Spring		Units
xx-xxx	SCS Elective	9
xx-xxx	Humanities and Arts Elective	9
xx-xxx	Free Elective	9
xx-xxx	Science and Engineering Elective	9
		36

Minimum number of units required for the degree:360

The flexibility in the curriculum allows many different schedules, of which the above is only one possibility. Some elective courses are offered only once per year (Fall or Spring). AI cluster electives (decision making and robotics, machine learning, perception and language, and human-AI interaction) may be taken in any order and in any semester if prerequisites are met and seats are available. Constrained electives are shown in the specific semesters in the schedule above as an example only. Students should consult with their academic advisor to determine the best elective options depending on course availability, their academic interests and their career goals.

Additional Major in Artificial Intelligence

Students interested in pursuing an additional major in Artificial Intelligence should first consult with the Program Administrator (bsai@cs.cmu.edu). Students must have all prerequisites completed, 21-112 or 21,120, 15-122, 15-150, one of 15-210, 15-213, or 15-251, as well as 15-281 or 10-315. Students must earn a "B" average in all prerequisite coursework in order to be admitted to the additional major. The additional major requires 6 mathematics courses, 5 computer science courses, 2 artificial intelligence courses, 4 courses from AI cluster areas, 1 course in ethics, and 1 course in human cognition.

Prerequisites

(1 course)		Units
15-112	Fundamentals of Programming and Computer Science	12

The following courses are required for the Addition Major in Artificial Intelligence:

Math and Statistics Core

(6 courses)		Units
21-112	Calculus II	10
or 21-120	Differential and Integral Calculus	
21-127	Concepts of Mathematics	12
or 21-128	Mathematical Concepts and Proofs	
or 15-151	Mathematical Foundations for Computer Science	
21-122	Integration and Approximation	10
21-241	Matrices and Linear Transformations	11
Probability and Statistics (one of)		
36-218	Probability Theory for Computer Scientists	9
15-259	Probability and Computing (if taken Sp24 or later)	12
21-325-36-226	Probability - Introduction to Statistical Inference	18
36-225-36-226	Introduction to Probability Theory - Introduction to Statistical Inference	18
36-235-36-236	Probability and Statistical Inference I-II	9
Modern Regression Course		
36-401	Modern Regression	9

Computer Science Core

(5 courses)		Units
15-122	Principles of Imperative Computation	12
15-150	Principles of Functional Programming	12
15-210	Parallel and Sequential Data Structures and Algorithms	12
15-213	Introduction to Computer Systems	12
15-251	Great Ideas in Theoretical Computer Science	12

Artificial Intelligence Core

(2 courses)		Units
15-281	Artificial Intelligence: Representation and Problem Solving	12
10-315	Introduction to Machine Learning (SCS Majors)	12

AI Cluster Electives

(4 courses, one from each cluster area)		Units
Cognition and Action Cluster (1 course)		
15-386	Neural Computation	9
15-482	Autonomous Agents	12
15-494	Cognitive Robotics: The Future of Robot Toys	12
16-350	Planning Techniques for Robotics	12
16-362	Mobile Robot Algorithms Laboratory	12
16-384	Robot Kinematics and Dynamics	12
Machine Learning Cluster (1 course)		
10-403	Deep Reinforcement Learning & Control	12
10-405	Machine Learning with Large Datasets (Undergraduate)	12
10-414	Deep Learning Systems: Algorithms and Implementation	12
10-417	Intermediate Deep Learning	12
10-418	Machine Learning for Structured Data	12
10-422	Foundations of Learning, Game Theory, and Their Connections	12
10-423	Generative AI	12
10-425	Introduction to Convex Optimization	12
11-441	Machine Learning with Graphs	9
11-485	Introduction to Deep Learning	9
36-402	Advanced Methods for Data Analysis	9
Perception and Language Cluster (1 course)		
11-411	Natural Language Processing	12
11-442	Search Engines	9
11-492	Speech Technology for Conversational AI	12
15-387	Computational Perception	9
15-463	Computational Photography	12
16-385	Computer Vision	12
Human-AI Interaction Cluster (1 course)		
05-317	Design of Artificial Intelligence Products	12
05-318	Human AI Interaction	12
05-391	Designing Human Centered Software	12
16-467	Introduction to Human Robot Interaction	12

Ethics and Human Cognition

(2 courses, one from each cluster area)		
Ethics (1 course)		
16-161	ROB Seminar: Artificial Intelligence and Humanity	12
16-735	Ethics and Robotics	12
17-200	Ethics and Policy Issues in Computing	9
80-249	AI, Society, and Humanity	9
Human Cognition (1 course)		
85-211	Cognitive Psychology	9
85-213	Human Information Processing and Artificial Intelligence	9
85-370	Perception	9
85-345	Meaning in Mind and Brain	9
85-408	Visual Cognition	9
85-435	Biologically Intelligent Exploration	9

*Note that Concepts in Artificial Intelligence (07-180) is not required for additional majors, although students interested in the additional major in AI are encouraged to take 07-180 prior to taking 15-281 or 10-315.

Double Counting Restrictions

Students pursuing an additional major in AI can double count at most **five courses** total, from the Computer Science Core, the Artificial Intelligence Core, and the AI Cluster Electives, towards all other majors and minors they're pursuing. The Mathematics, Ethics, and Human Cognition courses may double count without restriction, except for 36-402 (Advanced Methods for Data Analysis), which is part of the Machine Learning Cluster. Students with majors that overlap substantially with AI should consult with the Program Administrator (bsai@andrew.cmu.edu) to review their audit for any potential issues.

Artificial Intelligence Minor

Students interested in pursuing a minor in Artificial Intelligence should first consult with the Program Administrator (bsai@cs.cmu.edu) after completion of the prerequisites and 15-281 or 10-301/10-315. Students must earn a "C" average in all prerequisite coursework (including 15-281 or 10-301/10-315) in order to be admitted to the minor. The minor includes 3 required core courses, and 5 courses from AI cluster areas.

Prerequisites

(4 courses)		Units
15-122	Principles of Imperative Computation	12
21-112	Calculus II	10
or 21-120	Differential and Integral Calculus	
or 21-259	Calculus in Three Dimensions	
21-127	Concepts of Mathematics	12
or 21-128	Mathematical Concepts and Proofs	
or 15-151	Mathematical Foundations for Computer Science	
21-240	Matrix Algebra with Applications	10
or 21-241	Matrices and Linear Transformations	

The following courses are required for the Minor in Artificial Intelligence:

Required Core

(3 courses) *Two mini courses can be combined to form one 9 unit course.		Units
15-259	Probability and Computing	9-12
or 21-325	Probability	
or 36-218	Probability Theory for Computer Scientists	
or 36-225	Introduction to Probability Theory	
or 36-235	Probability and Statistical Inference I	
15-281	Artificial Intelligence: Representation and Problem Solving	12
10-301	Introduction to Machine Learning	12
or 10-315	Introduction to Machine Learning (SCS Majors)	

Technical Electives

(2 courses from any of the three areas)		Units
Cognition and Action Cluster		
15-386	Neural Computation	9
15-482	Autonomous Agents	12
15-494	Cognitive Robotics: The Future of Robot Toys	12
16-350	Planning Techniques for Robotics	12
16-362	Mobile Robot Algorithms Laboratory	12
16-384	Robot Kinematics and Dynamics	12
85-213	Human Information Processing and Artificial Intelligence	9
85-412	Cognitive Modeling	9
85-419	Introduction to Parallel Distributed Processing	9
85-435	Biologically Intelligent Exploration	9
Machine Learning Cluster		
10-403	Deep Reinforcement Learning & Control	12
10-405	Machine Learning with Large Datasets (Undergraduate)	12
10-414	Deep Learning Systems: Algorithms and Implementation	12
10-417	Intermediate Deep Learning	12
10-418	Machine Learning for Structured Data	12
10-422	Foundations of Learning, Game Theory, and Their Connections	12
10-423	Generative AI	12
10-425	Introduction to Convex Optimization	12
11-441	Machine Learning with Graphs	9
11-485	Introduction to Deep Learning	9
15-388	Practical Data Science	9
or 67-364	Practical Data Science	
36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9
Perception and Language Cluster		

11-411	Natural Language Processing	12
11-442	Search Engines	9
11-492	Speech Technology for Conversational AI	12
15-387	Computational Perception	9
15-463	Computational Photography	12
16-385	Computer Vision	12
85-370	Perception	9
85-345	Meaning in Mind and Brain	9
85-408	Visual Cognition	9

Societal Aspects of AI

(1 course from one of the two cluster areas) *Two mini courses can be combined to form one 9 unit course.		Units
Human-AI Interaction Cluster		
05-317	Design of Artificial Intelligence Products	12
05-318	Human AI Interaction	12
05-391	Designing Human Centered Software	12
16-467	Introduction to Human Robot Interaction	12
AI and Humanity Cluster		
16-735	Ethics and Robotics	12
17-200	Ethics and Policy Issues in Computing	9
79-302	Killer Robots? The Ethics, Law, and Politics of Drones and A.I. in War	9
80-249	AI, Society, and Humanity	9
88-230	Human Intelligence and Human Stupidity	9
88-275	Bubbles: Data Science for Human Minds	9
90-442	Critical AI Studies for Public Policy	6
94-441	Ethics and Politics of Data	6

Double Counting Restriction

Students pursuing a minor in AI can double count, at most, **two courses** total from the AI course requirements towards all other majors and minors they're pursuing. Students with majors that overlap substantially with AI should consult with the Program Administrator (bsai@andrew.cmu.edu) to review their audit for any potential issues.

Computational Biology Program

Russell Schwartz, PhD, Department Head
Location: GHC 7725

Phillip Compeau, PhD, Program Director & Assistant Dept. Head
Location: GHC 7403

Tara Seman, Academic Program Manager
Location: GHC 7721
cbd.cmu.edu (http://cbd.cmu.edu)

Bachelor of Science in Computational Biology

Success in computational biology requires significant technical knowledge of fundamental computer science as well as a broad biological intuition and general understanding of experimental biology. However, most importantly, it requires students who can integrate their knowledge by making connections between the two fields.

There is significant industry demand for excellent computational biology students, in biotech, pharmaceuticals, and biomedical research. Both established companies and startups struggle to find employees with the correct skillset, and our students will be able to take advantage of the fact that an undergraduate computational biology major has the rigorous training required to handle the challenges of modern research that is not provided by any of our peer institutions.

Students in the B.S. program in Computational Biology are expected to acquire the following skills upon graduation:

- Understand the fundamentals of single and multi-variable calculus, as used to construct models of biological systems.
- Construct their own logical mathematical proofs and later apply these proof techniques to theorems in algorithms and theoretical computer science.
- Obtain a firm grounding in probability and statistics necessary for interpretation of biomedical research results.
- Apply the fundamentals of modern chemistry and physics to biological molecules.
- Learn the principles of organization of biological systems on the cellular and molecular level.
- Interpret the connection of the principles of inheritance to the molecular level.
- Understand the relationship between macro and micro in terms of biological structure and function and the connection to metabolic pathways.
- Produce sound, stable, well-organized computer programs that scale well on large datasets.
- Understand the theoretical basis of modern computer science and integrate the inherent limitations of any computing system.
- Design algorithms based on efficient data structures to a variety of computational contexts to meet specified goals.
- Apply machine learning methods by which computers can “learn” from experience and apply these methods to genomic and biomedical data.
- Become familiar with structured biological databases and computational tools for operating on these databases.
- Construct mathematical/computational models of biological systems at differing scales and analyze the strengths and weaknesses of these models.
- Learn the fundamental laboratory techniques used in modern cell and molecular biology as well as the influence of computational methods on experimental design.
- Acquire a skillset of canonical algorithms applied in modern biological research and understand how these algorithms are applied to solve biological problems.
- Gain fluency in contemporary biomedical research topics and be able to interpret primary research results in computational biology.
- Understand the role of computation in biotechnology, pharmaceutical development, and medicine.

Degree Requirements

(students entering Fall 2024)

Students completing the Bachelor of Science in Computational Biology follow certain policies that apply to all SCS students; please consult the SCS policies page (p. 662) for a complete listing of these expectations.

Students must complete a **minimum of 360 units** for the degree in computational biology.

Mathematics/Statistics Core

21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
15-151	Mathematical Foundations for Computer Science (or 21-127/21-128 if not offered)	12
36-218	Probability Theory for Computer Scientists (Students taking 15-259 should take 36-326 or 15-260 instead. 15-260 is only open to students who have taken 15-259.)	9
or 36-226	Introduction to Statistical Inference	
or 36-326	Mathematical Statistics (Honors)	
or 36-235	Probability and Statistical Inference I	
or 15-260	Statistics and Computing	
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
Total Units		**52**

General Science Core

09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
33-121	Physics I for Science Students	12
or 33-141	Physics I for Engineering Students	
Total Units		**22**

Biological Core

03-151	Honors Modern Biology	10
or 03-121	Modern Biology	
03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	9
03-232	Biochemistry I (Students taking 03-231, including pre-med students, will take organic chemistry as a prerequisite, which will satisfy a biology elective requirement.)	9
or 03-231	Honors Biochemistry	
03-320	Cell Biology	9
Total Units		**37**

Computer Science Core

07-128	First Year Immigration Course (This course may be replaced by 03-201 or 03-202 if and only if 07-128 is not offered)	3
15-122	Principles of Imperative Computation	12
15-251	Great Ideas in Theoretical Computer Science	12
15-451	Algorithm Design and Analysis	12
or 15-351	Algorithms and Advanced Data Structures	
10-315	Introduction to Machine Learning (SCS Majors)	12
Total Units		**51**

Computational Biology Core

02-261	Quantitative Cell and Molecular Biology Laboratory	12
or 02-262	Computation and Biology Integrated Research Lab	
02-180	Great Ideas in Computational Biology I	5
02-181	Great Ideas in Computational Biology IIx	5
*02-251 is allowed if 02-180 and 02-181 are not offered		
02-402	Computational Biology Seminar	3
02-510	Computational Genomics	12
02-512	Computational Methods for Biological Modeling and Simulation	9
Total Units		**46**

Major Electives

02-3xx	Computational Biology Electives at 300 level or above	18-24
03-3xx	Biology Electives at 300 level or above (09-217 or 42-202 also count as biology electives)	9-12
xx-2xx	School of Computer Science Electives at 200 level or above, at least 9 units each. 15-150 is an acceptable 100-level course counting in this category, but the following exceptions are not allowed in this category: 02-201, 02-223, 02-250, 02-261, 02-262, 11-423, 15-351, 16-223, 17-200, 17-333, 17-562.	18-24
Total Units		**45-60**

Humanities & Arts

All candidates for the bachelor's degree in Computer Science must complete a minimum of 63 units offered by the College of Humanities & Social Sciences and/or the College of Fine Arts. These courses offer students breadth in their education and perspectives and provide students with a better appreciation of social, artistic, cultural, political and economic issues that can influence their effectiveness as computer scientists upon graduation.

Requirements for this component of the degree are listed under the SCS main page under General Education Requirements (p. 664).

Computing @ Carnegie Mellon (1 course)

The following course is required of all students to familiarize them with the campus computing environment:

99-101	Core@CMU	3

Free Electives

A free elective is any Carnegie Mellon course. However, a maximum of nine (9) units of Physical Education and/or Military Science (ROTC) and/or Student-Led (StuCo) courses may be used toward fulfilling graduation requirements.

Summary of Degree Requirements

Area	
Math/Stats Core	52
General Science Core	22
Biological Core	37
Computer Science Core	51
Computational Biology Core	46
Major Electives	45-60
General Education (Humanities & Arts)	63
Computing at Carnegie Mellon	3
Remaining Units	42-57
Total Units	**360**

Sample Course Sequence

The following is an example four-year course sequence for computational biology majors, assuming the student has credit for one semester of calculus. Note that our suggested courses during the first year fall are aligned with the sample course sequence for Computer Science majors (https://www.csd.cs.cmu.edu/content/sample-undergraduate-course-sequence/). All students interested in computational biology should take 03-121 (Modern Biology) or 03-151 (Honors Modern Biology) in their first fall and 0 (http://cbd.cmu.edu/education/courses-offered/02-251-great-ideas-in-comp-bio.html)2-180 (Great Ideas in Computational Biology I) and 02-181 (Great Ideas in Computational Biology II) in their first spring.

Some suggestions listed below are quite flexible. For example, physics and chemistry can be taken at any point in the student's first three semesters, and some of the computer science courses below can be replaced by other courses within the School of Computer Science, depending on a student's individual interests.

Other courses, such as cell biology, biochemistry, computational genomics, and biological modeling and simulation, are only offered in either the fall or the spring.

We discuss a tailored plan with our majors to ensure that courses are taken at the appropriate times, while affording each student the flexibility to explore their other interests at CMU.

Note: Before you arrive at CMU, you will take 99-101 Computing at Carnegie Mellon and 15-051, a Discrete Math primer, in your own time. These short courses are provided to incoming students for free.

First-Year		Second-Year	
Fall	**Spring**	**Fall**	**Spring**
07-128 First Year Immigration Course	02-251 Great Ideas in Computational Biology	02-261 Quantitative Cell and Molecular Biology Laboratory	02-xxx Computational Biology Elective
15-112 Fundamentals of Programming and Computer Science	15-122 Principles of Imperative Computation	21-241 Matrices and Linear Transformations	15-251 Great Ideas in Theoretical Computer Science
15-131 Great Practical Ideas for Computer Scientists	09-105 Introduction to Modern Chemistry I	33-121 Physics I for Science Students	03-232 Biochemistry I
15-151 Mathematical Foundations for Computer Science	21-259 Calculus in Three Dimensions	36-218 Probability Theory for Computer Scientists	03-221 Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis
03-151 Honors Modern Biology	76-101 Interpretation and Argument	15-150 Principles of Functional Programming	xx-xxx Humanities and Arts Elective
21-122 Integration and Approximation			

Third-Year		Fourth-Year	
Fall	**Spring**	**Fall**	**Spring**
02-512 Computational Methods for Biological Modeling and Simulation	02-402 Computational Biology Seminar	02-xxx Computational Biology Elective	xx-xxx Humanities and Arts Elective
03-320 Cell Biology	02-510 Computational Genomics	xx-xxx Humanities and Arts Elective	xx-xxx Free Elective
10-315 Introduction to Machine Learning (SCS Majors)	03-xxx Biology Elective	xx-xxx Free Elective	xx-xxx Free Elective
15-210 Parallel and Sequential Data Structures and Algorithms	15-451 Algorithm Design and Analysis	xx-xxx Free Elective	xx-xxx Free Elective
xx-xxx Humanities and Arts Elective	xx-xxx Humanities and Arts Elective		

Additional Major in Computational Biology

The Additional Major in Computational Biology is designed for undergraduate students wishing to study computational biology as a second field of study at Carnegie Mellon University in addition to their primary major.

The additional major is open to all students who complete the prerequisite coursework listed below, with the requirement that a student from outside SCS must have a 3.0 overall QPA when applying.

To prevent double-counting, students must complete at least seven courses of at least 9 units each as part of the additional major in computational biology (not including pre-requisites) that are unique to the additional major.

Students interested in the Additional Major in Computational Biology should contact the Computational Biology Undergrad Program Director.

Prerequisite Courses

02-250	Introduction to Computational Biology	12
02-180	Great Ideas in Computational Biology I	5
02-181	Great Ideas in Computational Biology IIx	5
*02-251 is allowed if 02-180 and 02-181 are not offered		
03-151	Honors Modern Biology	10
or 03-121	Modern Biology	
15-122	Principles of Imperative Computation	12
15-151	Mathematical Foundations for Computer Science	12
or 21-127	Concepts of Mathematics	
or 21-128	Mathematical Concepts and Proofs	
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
Total Units		**76**

Mathematics/Statistics Core

36-218	Probability Theory for Computer Scientists	9
or 36-226	Introduction to Statistical Inference	
or 36-326	Mathematical Statistics (Honors)	
or 36-235	Probability and Statistical Inference I	
or 15-260	Statistics and Computing	
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
Total Units		**20**

General Science Core

09-105	Introduction to Modern Chemistry I	10
or 09-107	Honors Chemistry: Fundamentals, Concepts and Applications	
33-121	Physics I for Science Students	12
or 33-141	Physics I for Engineering Students	
Total Units		**22**

Biological Core

03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	9
or 03-220	Genetics	
03-232	Biochemistry I (Students taking 03-231, including pre-med students, will take organic chemistry as a prerequisite, which will satisfy a biology elective requirement.)	9
or 03-231	Honors Biochemistry	
03-320	Cell Biology	9
Total Units		**27**

Computer Science Core

15-251	Great Ideas in Theoretical Computer Science	12
15-451	Algorithm Design and Analysis	12
or 15-351	Algorithms and Advanced Data Structures	
10-315	Introduction to Machine Learning (SCS Majors)	12
Total Units		**36**

Computational Biology Core

02-261	Quantitative Cell and Molecular Biology Laboratory	12
or 02-262	Computation and Biology Integrated Research Lab	
02-402	Computational Biology Seminar	3
02-510	Computational Genomics	12
02-512	Computational Methods for Biological Modeling and Simulation	9
Total Units		**36**

Major Electives

02-3xx	Computational Biology Electives at 300 level or above	18-24
03-3xx	Biology Electives at 300 level or above (09-217 or 42-202 also count as biology electives)	9-12
xx-2xx	School of Computer Science Electives at 200 level or above, at least 9 units each. 15-150 is an acceptable 100-level course counting in this category, but the following exceptions are not allowed in this category: 02-201, 02-223, 02-250, 02-261, 02-262, 11-423, 15-351, 16-223, 17-200, 17-333, 17-562.	18-24
Total Units		**45-60**

General Education (Humanities & Arts)

For specific courses that may be used to satisfy each elective, please consult the General Education Requirements for your primary major.

Computational Biology Minor

SCS Majors: Please see the Computational Biology Concentration (p. 761)

Phillip Compeau, PhD, *Director*
Tara Seman, *Program Manager*

The computational biology minor is open to students in any major of any college at Carnegie Mellon outside the School of Computer Science. The curriculum and course requirements are designed to maximize the participation of students from diverse academic disciplines. The program seeks to produce students with both basic computational skills and knowledge in biological sciences that are central to computational biology.

Students are encouraged to declare the minor as early as possible in their undergraduate careers and in all cases before their final semester so that the minor advisor can provide advice on their curriculum.

Why Minor in Computational Biology?

Computational Biology is concerned with solving biological and biomedical problems using mathematical and computational methods. It is recognized as an essential element in modern biological and biomedical research. There have been fundamental changes in biology and medicine over the past two decades due to spectacular advances in high throughput data collection for genomics, proteomics and biomedical imaging. The resulting availability of unprecedented amounts of biological data demands the application of advanced computational tools to build integrated models of biological systems, and to use them to devise methods of prevent or treat disease. Computational Biologists inhabit and expand the interface of computation and biology, making them integral to the future of biology and medicine.

Policy on Double Counting

No more than two courses may be double counted with your major's core requirements. Courses in the minor may not be counted towards another SCS minor. Consult the minor advisor for more information.

Curriculum Overview

The minor in computational biology requires a total of five courses: 3 core courses, 1 biology elective, and 1 computational biology elective, for a **total of at least 45 units**.

Prerequisites

Students must take two courses as prerequisites from the following:		Units
One of:		
03-151	Honors Modern Biology	10
03-121	Modern Biology	9
and one of:		
15-112	Fundamentals of Programming and Computer Science	12
15-110	Principles of Computing	10

Core Classes

Students must take two from the following courses:		
One of:		
02-250	Introduction to Computational Biology	12
*02-251 is allowed if 02-180 and 02-181 are not offered		
One of:		
02-261	Quantitative Cell and Molecular Biology Laboratory (03-343 Experimental Techniques in Molecular Biology may be substituted for 02-261 with permission of the minor advisor; 03-116 may be used to replace 02-261 if and only if the latter is not offered)	Var.
02-262	Computation and Biology Integrated Research Lab	Var.

ElectiveS

Three computational biology electives (02-XXX) at the 300 level or higher.

Computer Science Program

Srinivasan Seshan, Department Head, Computer Science
Location: GHC 7019

Mark Stehlik, Program Director, Assistant Dean for Outreach
Location: GHC 6205

Amy Weis, Program Coordinator, CS Undergraduate Office
Location: GHC 4115
www.csd.cs.cmu.edu (http://www.csd.cs.cmu.edu)

The B.S. program in Computer Science combines a solid core of Computer Science courses with the ability to gain additional depth through a required minor in a second subject or a concentration in a computing area. In addition, the curriculum provides breadth through numerous choices for science, engineering, humanities and fine arts courses. As computing is a discipline with strong links to many fields, this provides students with unparalleled flexibility to pursue allied (or non-allied) interests.

Students apply to, and are directly admitted into, the School of Computer Science. Admitted students may choose to pursue an undergraduate degree in Computer Science and, upon successful completion, are awarded a Bachelor of Science in Computer Science. Suitably prepared students from other Carnegie Mellon colleges are eligible to apply for internal transfer to the School of Computer Science and will be considered for transfer if grades in core CS requirements are sufficiently high and space is available.

Students in the B.S. program in Computer Science are expected to acquire the following skills upon graduation:

- Identify, use, design, develop and analyze appropriate abstractions and algorithms to solve problems while being able to prove the algorithm’s performance and correctness across a variety of metrics (e.g., time, space, parallel vs. sequential implementation, computability).
- Implement solutions to problems in domains such as artificial intelligence, graphics and sound, software engineering, and human-computer interaction, by applying the fundamentals of those areas to create solutions to current problems while being exposed to research developments that will enable them to adapt as the technology changes.
- Reason about and implement programs in various programming languages and paradigms
- Describe, specify, and develop large-scale, open-ended software systems subject to constraints such as performance and/or resource issues
- Communicate technical material effectively to technical and non-technical audiences
- Work both individually and in teams
- Recognize the social impact of computing and the attendant responsibility to consider the legal, moral and ethical implications of computing technologies.

Due to the tremendous number of ongoing research projects within the School, many students obtain part-time or summer jobs, or receive independent study credit, working on research while pursuing their undergraduate degree. Students seeking a research/graduate school career may pursue an intensive course of research, equivalent to four classroom courses, culminating in the preparation of a senior research thesis.

SCS also offers a B.S. degree in Artificial Intelligence, a B.S. degree in Computational Biology, a B.S. degree in Human-Computer Interaction, and a Bachelor's Degree in Computer Science and the Arts (jointly with the College of Fine Arts). More detail about the Artificial Intelligence major, the Computational Biology major and the Computer Science and the Arts program is available in separate sections of the Undergraduate Catalog. SCS offers additional majors in Computer Science (for non-CS majors), Human-Computer Interaction, and Robotics, and minors in Computational Biology, Computer Science (for non-CS majors), Human-Computer Interaction, Language Technologies, Machine Learning, Neural Computation, Robotics, and Software Engineering. Information about additional majors and minors in SCS besides those in Computer Science are listed in a separate section in the Undergraduate Catalog.

Curriculum - B.S. in Computer Science

The following requirements are for students entering Fall 2023.

Computer Science

Computer Science Core (all of the following):		Units
07-128	First Year Immigration Course	3
15-122	Principles of Imperative Computation (students without credit or a waiver for 15-112, Fundamentals of Programming and Computer Science, must take 15-112 before 15-122)	12
15-150	Principles of Functional Programming	12
15-210	Parallel and Sequential Data Structures and Algorithms	12
15-213	Introduction to Computer Systems	12
15-251	Great Ideas in Theoretical Computer Science	12
15-451	Algorithm Design and Analysis	12

One Artificial Intelligence elective (min. 9 units). Students will be able to tackle complex, real-world problems using techniques from Artificial Intelligence, including symbolic and probabilistic reasoning, machine learning, optimization, and perception.

10-315	Introduction to Machine Learning (SCS Majors)	12
11-411	Natural Language Processing	12
11-485	Introduction to Deep Learning	9
15-281	Artificial Intelligence: Representation and Problem Solving	12
15-386	Neural Computation	9
16-384	Robot Kinematics and Dynamics	12
16-385	Computer Vision	12
others as designated by the CS Undergraduate Program		

One Domains elective (min. 9 units). Students will gain expertise in fundamental principles from a larger domain of computer science not already represented by other constrained categories, currently logic and languages, systems, and artificial intelligence (which includes machine learning, language technologies, and robotics). Students will be able to apply theoretical and computational techniques from the Computer Science core to an introductory study of another major subarea of Computer Science.

02-251	Great Ideas in Computational Biology	12
05-391	Designing Human Centered Software	12
11-324	Human Language for Artificial Intelligence	12
15-322	Introduction to Computer Music	9
15-330	Introduction to Computer Security	12
15-362	Computer Graphics	12
15-455	Undergraduate Complexity Theory	9
17-313	Foundations of Software Engineering	12
others as designated by the CS Undergraduate Program		

One Logics/Languages elective (min. 9 units). Students will master techniques for rigorous, formal reasoning about programs or systems, rooted in their logical foundations.

15-311	Logic and Mechanized Reasoning	9
15-312	Foundations of Programming Languages	12
15-316	Software Foundations of Security and Privacy	9
15-317	Constructive Logic	9
15-414	Bug Catching: Automated Program Verification	9
17-355	Program Analysis	12
17-363	Programming Language Pragmatics	12
80-413	Category Theory	9
others as designated by the CS Undergraduate Program		

One Software Systems elective (min. 12 units). Students will: 1. be able to describe how the properties of modern hardware (e.g., processor architecture, networks, storage) influence the design and implementation of software systems, such as through reasoning about concurrency and performance. 2. be able to analyze failures and / or resource limitations of physical systems and plan for their mitigation or management. 3. be able to develop abstractions based on lower-level primitives to manage the failures or other difficulties inherent in working with hardware. 4. demonstrate their learning through significant project / system implementations, requiring both course-specific knowledge as well as general system-building skills (i.e., not just programming, but also design, debugging, testing, etc.). The programming tasks together constitute a significant fraction of the course grade (e.g., 40% or more).		
15-410	Operating System Design and Implementation	15
15-411	Compiler Design	15
15-418	Parallel Computer Architecture and Programming	12
15-440	Distributed Systems	12
15-441	Networking and the Internet	12
15-445	Database Systems	12
others as designated by the CS Undergraduate Program		

Two School of Computer Science electives:	Units
These electives can be from any SCS department (Computer Science [15-], Computational Biology [02-], Human-Computer Interaction [05-], Machine Learning [10-], Language Technologies [11-], Robotics [16-], or Software & Societal Systems [17-]). They must be 200-level or above and at least 9 units each, with the following exceptions:	18
ADDITIONS: 1) students who take two of the major-intro mini-courses (02-180, 05-180, 07-180, or 16-180) during their first year may combine these two mini-courses together to count as one SCS elective; 2) 15-195 and 15-295 can be combined to count as one SCS elective; 3) 07-400 and 07-599 are countable as SCS electives.	
DELETIONS: 1) the following courses do NOT count as SCS electives: 02-201, 02-223, 02-250, 02-261, 05-200, 11-423, 15-351, 16-211, 16-223, 16-224, 16-397, 16-480, 17-200, 17-333, 17-562; 2) some IDeATe courses and some SCS undergraduate and graduate courses might not be allowed based on course content. Always consult with a CS undergraduate advisor before registration to determine eligibility for this requirement.	

Mathematics

All of the following Mathematics courses:		
15-151	Mathematical Foundations for Computer Science (if not offered, substitute 21-127 or 21-128)	12
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
21-259	Calculus in Three Dimensions	10
or 21-266	Vector Calculus for Computer Scientists	
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
Plus one of the following four Probability choices:		
15-259	Probability and Computing	12
21-325	Probability	9
36-218	Probability Theory for Computer Scientists	9
36-225-36-226	Introduction to Probability Theory - Introduction to Statistical Inference (must take both courses in this sequence to satisfy requirement)	18

Technical Communication

Learning Objectives:

Audience
Students will be able to analyze the audience or audiences of a work: who the stakeholders are, what those stakeholders are trying to accomplish, and how persuasive communication can help students achieve their goals.

Written Mechanics
Students will practice developing their professional writing voice, paying attention to spelling, grammar, style, and the use of visual information.

Adaptation
Students will be able to adapt expert-level information for a general audience, across textual, graphical, and oral presentation.

Genres/Templates
Students will practice developing information in a variety of communication contexts, connecting areas of content in their own voice, and leading the reader through a cogent sequence of ideas while working within the constraints of a particular genre or template.

Peer Review
Students will practice reading and revising the work of themselves and their peers.

Oral Presentation Mechanics
Students will prepare for the real-time act of presenting to an audience, including delivery, practice, venue setup, and managing presentation support (slides, props, etc.).

Oral Presentation Development
Students will explore formal and informal modes of communication, selecting, organizing and explaining information for a real-time audience, and increasing clarity with use of structure and style.

Group Work
Students will practice skills to help them work as a team, stay on track, and produce a group deliverable.

One Technical Communications course:		Units
07-300	Research and Innovation in Computer Science	9
17-200	Ethics and Policy Issues in Computing	9
76-270	Writing for the Professions	9

Science and Engineering

All candidates for the bachelor's degree in Computer Science must complete a minimum of 36 units offered by the Mellon College of Science and/or the College of Engineering (CIT). These courses offer students an opportunity to explore scientific and engineering domains that can influence their effectiveness as computer scientists upon graduation.

Requirements for this component of the degree are listed under the SCS main page under General Education Requirements (p. 664).

Humanities and Arts

All candidates for the bachelor's degree in Computer Science must complete a minimum of 63 units offered by the College of Humanities & Social Sciences and/or the College of Fine Arts. Some courses from the Tepper School of Business also qualify for this requirement. These courses offer students breadth in their education and perspectives and provide students with a better appreciation of social, artistic, cultural, political and economic issues that can influence their effectiveness as computer scientists upon graduation.

Requirements for this component of the degree are listed under the SCS main page under General Education Requirements (p. 664).

Required Minor or Concentration

Students completing the bachelor's degree in Computer Science must complete either a minor outside of SCS or a concentration within SCS. A minor is a sequence of (typically 5-6) courses within a particular department to give students a core of a specific discipline but not an entire major of study. Refer to the sections for other CMU colleges for details about available non-SCS minors. An SCS concentration is a sequence of (typically 4-5) courses within an SCS department to give students further depth in specific areas of research important to SCS. SCS concentrations are available only to SCS students and assume that these students have a significant core knowledge in Computer Science including 15-210, 15-213 and 15-251. See the SCS Concentrations section for a list of available concentrations and their requirements. Completion of an additional major (or dual degree) also satisfies this requirement. Students should consult with their academic advisor to plan for their desired minor or concentration starting in the sophomore year.

Double Counting

In general, courses taken in satisfaction of the minor or additional major may also count toward any general education category in the CS major (i.e. courses outside of the Computer Science and Mathematics requirements). Double counting toward Computer Science and Mathematics courses in the CS major is strictly limited and depends on the chosen minor (or additional major). In general, students may double count at most 5 of the 12 core Computer Science requirements toward all other declared additional majors and minors. Additional majors and minors have their own double counting rules as well. Consult with a CS undergraduate advisor and an advisor from the department of the minor (or additional major) for specific restrictions on double counting.

Computing @ Carnegie Mellon (1 course)

The following course is required of all students to familiarize them with the campus computing environment:

99-101	Core@CMU	3

Free Electives

A free elective is any Carnegie Mellon course. However, a maximum of nine (9) units of Physical Education and/or Military Science (ROTC) and/or Student-Led (StuCo) courses may be used toward fulfilling graduation requirements.

Summary of Degree Requirements:

Area	Courses	**Units**
Computer Science (core courses, constrained electives, and SCS electives)	12	**125**
Mathematics	6	**58**
Technical Communication	1	**9**
Science/Engineering	4	**36**
Humanities/Arts	7	**63**
Minor or Concentration Requirement/Free electives	Varies	**63**
Computing @ Carnegie Mellon	1	**3**
First Year Seminar	1	**3**
		360

Sample Course Sequence

The sample given below is for a student who already has credit for introductory programming and one semester of calculus. Students with credit for two semesters of calculus may start with a more advanced math class (e.g. 21-241) in their first year. Students with no credit for introductory programming and/or one semester of calculus will take 15-112 and/or 21-120 in their first semester and shift a few courses to later semesters after consulting with their academic advisor; these students should still be able to complete their degree in four years. It is recommended that students keep their academic load lighter for their Senior Fall semester to account for offsite job interviews or for their Senior Spring semester to account for visits to graduate schools.

Freshman Year:

Fall		Units
07-128	First Year Immigration Course	3
07-131	Great Practical Ideas for Computer Scientists (optional, not required for CS major)	2
15-122	Principles of Imperative Computation	12
15-151	Mathematical Foundations for Computer Science (if not offered, substitute 21-127)	12
21-122	Integration and Approximation	10
76-101	Interpretation and Argument	9
99-101	Core@CMU	3
		51

Spring		Units
15-150	Principles of Functional Programming	12
15-213	Introduction to Computer Systems	12
21-259	Calculus in Three Dimensions	10
xx-180	SCS Major Intro Mini	5
xx-xxx	Humanities and Arts Elective	9
		48

Sophomore Year:

Fall		Units
15-210	Parallel and Sequential Data Structures and Algorithms	12
21-241	Matrices and Linear Transformations	11
xx-xxx	Science/Engineering Course	9
xx-xxx	Humanities and Arts Elective	9
xx-xxx	Minor Requirement / Free Elective	9
		50

Spring		Units
15-251	Great Ideas in Theoretical Computer Science	12
xx-xxx	Computer Science: Domains Elective*	9
xx-xxx	Probability Course*	9
xx-xxx	Science/Engineering Course	9
xx-xxx	Humanities and Arts Elective	9
		48

Junior Year:

Fall		Units
15-451	Algorithm Design and Analysis	12
xx-xxx	Computer Science: Logic/Languages Elective*	9
xx-xxx	Technical Communications Course*	9
xx-xxx	Science/Engineering Course	9
xx-xxx	Minor Requirement / Free Elective	9
		48

Spring		Units
15-xxx	Computer Science: Systems Elective*	12
xx-xxx	Computer Science: Artificial Intelligence Elective*	9
xx-xxx	Science/Engineering Course	9
xx-xxx	Humanities and Arts Elective	9
xx-xxx	Minor Requirement / Free Elective	9
		48

Senior Year:

Fall		Units
xx-xxx	School of Computer Science Elective	9
xx-xxx	Humanities and Arts Elective	9
xx-xxx	Minor Requirement / Free Elective	9
xx-xxx	Minor Requirement / Free Elective	9
		36

Spring		Units
xx-xxx	School of Computer Science Elective	9
xx-xxx	Humanities and Arts Elective	9
xx-xxx	Minor Requirement / Free Elective	9
xx-xxx	Minor Requirement / Free Elective	9
		36

Minimum number of units required for the degree: 360

*The flexibility in the curriculum allows many different schedules, of which the above is only one possibility. Some elective courses are offered only once per year (Fall or Spring). Constrained electives (probability, logic/languages, software systems, artificial intelligence and domains) may be taken in any order and in any semester if prerequisites are met and seats are available. Constrained electives are shown in the specific semesters in the schedule above as an example only. Students should consult with their academic advisor to determine the best elective options depending on course availability, their academic interests and their career goals.

Undergraduate Research Thesis

CS majors may use the SCS Honors Research Thesis as part of their degree. The SCS Honors Undergraduate Research Thesis (07-599) typically starts in the fall semester of the senior year, and spans the entire senior year. Students receive a total of 36 units of academic credit for the thesis work, 18 units per semester. Up to 18 units can be counted toward CS elective requirements (9 per semester for 2 semesters maximum). Students interested in research may also consider using Research and Innovation in Computer Science (07-300, 9 units) as their technical communications requirement in their junior year since this course will introduce students to various research projects going on in the School of Computer Science that may lead to a senior thesis. This course leads to a subsequent Research Practicum in Computer Science (07-400, 12 units) that allows students to complete a small-scale research study or experiment and present a research poster. Students who use 15-400 to start their senior thesis can use these units toward the required 36 units.

For more information about the SCS Honors Research Thesis, refer to the SCS Honors Research Thesis (p. 667) section for learning objectives, application requirements and expected outcomes.

Dual Degree in Computer Science

Students wishing to pursue a Dual Degree in Computer Science are required to apply in the same way as students wishing to transfer into the Computer Science major. Details are given in the SCS Policies section. Besides the student's primary degree requirements, a student accepted for Dual Degree in CS is required to complete at least 450 units in total and meet all requirements for the CS major including all general education requirements (humanities/arts and science/engineering). Dual degree students do not need to complete 07-128, and these students will replace 15-151 with either 21-127 or 21-128. Since the CS major requires at least a minor or concentration in another area, the student's primary major will substitute for this requirement. Note that the primary major must be completed prior to or at the same time as the dual degree in CS to satisfy the minor requirement; a dual degree in CS cannot be certified if the primary degree is not completed. Students should consult with the Assistant Dean in the CS Undergraduate Office and/or their CS academic advisor to review all requirements, once approved.

Double-Counting Restriction

Students pursuing a Dual Degree in Computer Science must complete all requirements for the CS primary major (except 07-128 which is not required and 15-151 which will be replaced with 21-127 or 21-128). In addition, at most 5 of the 12 computer science requirements can double count with all other declared majors and minors. Students, especially from interdisciplinary majors or with multiple majors or minors, are urged to consult with the Assistant Dean or Undergraduate Program Coordinator in the CS Undergraduate Office to determine double-counting restrictions specific to their own situations.

Computer Science Additional Major

Students interested in pursuing an additional major in Computer Science should first consult with the Program Coordinator in the CS Undergraduate Office. Students are expected to complete the requirements for the CS minor first before continuing on to the additional major. Completion of the CS additional major requires 12 computer science courses (not including 15-110 and 15-112 if needed), 5 mathematics courses, and 1 technical communication course. Students are expected to complete all courses for the additional major with an average QPA of 3.0 or higher.

Declaration for the additional major is allowed only after all math requirements are completed or in progress, and at least 9 of the 12 CS requirements (core and electives) are completed or in progress. Due to high demand, seats in upper-level CS courses are not guaranteed for additional majors so students should plan to be flexible in selecting constrained and general electives. Acceptance to complete a Computer Science additional major is not guaranteed and depends on student performance and seat availability.

The following courses are required for the Additional Major in Computer Science:

Computer Science requirements (12 courses):

Core courses (all are required):		Units
15-122	Principles of Imperative Computation	12
15-150	Principles of Functional Programming	12
15-210	Parallel and Sequential Data Structures and Algorithms	12
15-213	Introduction to Computer Systems	12
15-251	Great Ideas in Theoretical Computer Science	12
15-451	Algorithm Design and Analysis	12

One Artificial Intelligence elective (minimum 9 units). Students will be able to tackle complex, real-world problems using techniques from Artificial Intelligence, including symbolic and probabilistic reasoning, machine learning, optimization, and perception.		Units
10-315	Introduction to Machine Learning (SCS Majors) (or 10-301)	12
11-411	Natural Language Processing	12
11-485	Introduction to Deep Learning	9
15-281	Artificial Intelligence: Representation and Problem Solving	12
15-386	Neural Computation	9
16-384	Robot Kinematics and Dynamics	12
16-385	Computer Vision	12
others as designated by the CS Undergraduate Program		

One Domains elective (minimum 9 units). Students will gain expertise in fundamental principles from a larger domain of computer science not already represented by other constrained categories, currently logic and languages, systems, and artificial intelligence (which includes machine learning, language technologies, and robotics). Students will be able to apply theoretical and computational techniques from the Computer Science core to an introductory study of another major subarea of Computer Science.		Units
02-251	Great Ideas in Computational Biology	12
05-391	Designing Human Centered Software	12
11-324	Human Language for Artificial Intelligence	12
15-322	Introduction to Computer Music	9
15-330	Introduction to Computer Security	12
15-362	Computer Graphics	12
15-455	Undergraduate Complexity Theory	9
17-313	Foundations of Software Engineering	12
others as designated by the CS Undergraduate Program		

One Logic & Languages elective (minimum 9 units). Students will master techniques for rigorous, formal reasoning about programs or systems, rooted in their logical foundations.		Units
15-311	Logic and Mechanized Reasoning	9
15-312	Foundations of Programming Languages	12
15-316	Software Foundations of Security and Privacy	9
15-317	Constructive Logic	9
15-414	Bug Catching: Automated Program Verification	9
17-355	Program Analysis	12
17-363	Programming Language Pragmatics	12
80-413	Category Theory	9
others as designated by the CS Undergraduate Program		

One Systems elective (minimum 12 units). Students will 1. be able to describe how the properties of modern hardware (e.g., processor architecture, networks, storage) influence the design and implementation of software systems, such as through reasoning about concurrency and performance. 2. be able to analyze failures and / or resource limitations of physical systems and plan for their mitigation or management. 3. be able to develop abstractions based on lower-level primitives to manage the failures or other difficulties inherent in working with hardware. 4. demonstrate their learning through significant project / system implementations, requiring both course-specific knowledge as well as general system-building skills (i.e., not just programming, but also design, debugging, testing, etc.). The programming tasks together constitute a significant fraction of the course grade (e.g., 40% or more).		Units
15-410	Operating System Design and Implementation	15
15-411	Compiler Design	15
15-418	Parallel Computer Architecture and Programming	12
15-440	Distributed Systems	12
15-441	Networking and the Internet	12
15-445	Database Systems	12
others as designated by the CS Undergraduate Program		

Two School of Computer Science electives (minimum 18 units):	
These electives can be from any SCS department (Computer Science [15-xxx], Computational Biology [02-xxx], Human-Computer Interaction [05-xxx], Machine Learning [10-xxx], Language Technologies [11-xxx], Robotics [16-xxx], or Software & Societal Systems [17-xxx]). They must be 200-level or above and at least 9 units each, with the following exceptions:	18
ADDITION: 15-195 and 15-295 can be combined to count as one SCS elective.	

DELETIONS: 1) the following courses do NOT count as SCS electives: 02-201, 02-223, 02-250, 02-261, 05-200, 11-423, 15-351, 16-211, 16-223, 16-224, 16-397, 16-480, 17-200, 17-333, 17-562; 2) some IDeATe courses and some SCS undergraduate and graduate courses might not be allowed based on course content. Always consult with a CS undergraduate advisor before registration to determine eligibility for this requirement.

Math requirements (minimum 5 courses):

		Units
All of the following courses:		
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	12
or 21-128	Mathematical Concepts and Proofs	
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
21-259	Calculus in Three Dimensions	10
or 21-266	Vector Calculus for Computer Scientists	
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
Plus one of the following:		
15-259	Probability and Computing	12
21-325	Probability	9
36-218	Probability Theory for Computer Scientists	9
36-226	Introduction to Statistical Inference (for students already taking 36-219 or 36-225)	9

Technical Communication requirement (1 course)

Learning Objectives:

Audience
Students will be able to analyze the audience or audiences of a work: who the stakeholders are, what those stakeholders are trying to accomplish, and how persuasive communication can help students achieve their goals.

Written Mechanics
Students will practice developing their professional writing voice, paying attention to spelling, grammar, style, and the use of visual information.

Adaptation
Students will be able to adapt expert-level information for a general audience, across textual, graphical, and oral presentation.

Genres/Templates
Students will practice developing information in a variety of communication contexts, connecting areas of content in their own voice, and leading the reader through a cogent sequence of ideas while working within the constraints of a particular genre or template.

Peer Review
Students will practice reading and revising the work of themselves and their peers.

Oral Presentation Mechanics
Students will prepare for the real-time act of presenting to an audience, including delivery, practice, venue setup, and managing presentation support (slides, props, etc.).

Oral Presentation Development
Students will explore formal and informal modes of communication, selecting, organizing and explaining information for a real-time audience, and increasing clarity with use of structure and style.

Group Work
Students will practice skills to help them work as a team, stay on track, and produce a group deliverable.

One Technical Communications course:		Units
07-300	Research and Innovation in Computer Science	9
17-200	Ethics and Policy Issues in Computing	9
76-270	Writing for the Professions	9

Double-Counting Restriction

Students pursuing an Additional Major in Computer Science must complete all requirements listed above. In addition, at most 5 of the 12 computer science requirements can be double counted toward all other declared majors and minors. The mathematics and technical communication requirements can be double counted without restriction. Students, especially from interdisciplinary majors or with multiple majors or minors, are urged to consult with the Computer Science Program Director or the Undergraduate Program Coordinator in the CS Undergraduate Office to determine double-counting restrictions specific to their own situations.

Computer Science Minor

Students interested in pursuing a minor in Computer Science should first consult with the Program Coordinator in the CS Undergraduate Office after completion of the prerequisites, 15-122, 15-150 and with at least one of the 200-level required courses in progress. Students are expected to complete all courses for the minor with a C or higher (for a minor average QPA of 2.0 or higher).

The following courses are required for the Minor in Computer Science:

Prerequisites:		Units
15-112	Fundamentals of Programming and Computer Science (some students may need to take 15-110 prior to 15-112 for additional preparation)	12
21-127	Concepts of Mathematics	12
or 21-128	Mathematical Concepts and Proofs	

Computer Science core courses:		
15-122	Principles of Imperative Computation	12
15-150	Principles of Functional Programming	12
15-210	Parallel and Sequential Data Structures and Algorithms	12

One of the following Computer Science core courses:		
15-213	Introduction to Computer Systems	12
15-251	Great Ideas in Theoretical Computer Science	12

Two additional Computer Science electives, of at least 9 units each:	
CS elective courses must be 15-213 or higher, at least 9-units each. 15-351 cannot be used. One course can be from any other SCS department besides the Computer Science Department, with prior approval.	18
Note: students who have to take 15-213/18-213 or 15-251 as part of another degree program are required to replace that CS core course requirement with another CS elective (15-xxx) as defined above, for a total of 3 additional CS electives.	

Double-Counting Restriction

Students may double-count a maximum of 2 courses for the CS minor (not including the prerequisites) toward all other majors and minors. Students, especially from computing-related majors, interdisciplinary majors or with multiple majors or minors, are urged to consult with the Computer Science Program Director or the Undergraduate Program Coordinator in the CS Undergraduate Office to review double-counting restrictions specific to their own situations.

Human-Computer Interaction Program

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Undergraduate Major in HCI

In 2020, Carnegie Mellon University became one of the first universities worldwide to offer a primary major in Human-Computer Interaction (HCI). Students within the School of Computer Science (SCS) can now declare HCI as their primary major.

About the B.S. in HCI

The Bachelor of Science in Human-Computer Interaction will produce HCI specialists who are technically skilled and adept at designing and prototyping interactive solutions with the latest digital technologies. Students graduating from the HCI primary will have a unique perspective on how digital products and services impact humans, and also how they can be designed to have a positive impact.

Students in this major will have a strong Computer Science core of programming, algorithms, systems and mathematical foundations, just like the other undergraduate majors in SCS. They will specialize by making core elements of human-computer interaction the primary focus of their upper-level classes, and can explore a large range of HCI topics in greater depth through their elective choices. In the final capstone project course, they will work as part of an interdisciplinary student team to produce innovative digital solutions for a problem presented by a client.

Responding to the Demand for HCI in Tech

Our corporate partners spoke of the need for competitive entry-level professionals who can enter the workforce with a solid understanding of HCI. This technical program will prepare graduates to understand and create innovative services, systems and applications that serve all people. Students will have the opportunity to design for a range of digital technologies, including web, mobile, IoT, VR, AR, sensors, fabrication, gadgets and more.

There is also a need for HCI practitioners with a "T-shaped person" knowledgebase. That is, professionals who exhibit broad knowledge and diverse technical skills, as well as a valuable focus in a specialization area. HCI majors will build a broad foundational knowledge in computing, mathematics and statistics; development skills for digital and interactive technologies; and experience with methods of rapid prototyping, all of which will help them to collaborate with their peers in related fields.

Opportunities for B.S. in HCI Grads

Graduates with this rigorous background will serve key roles in the tech industry. B.S. in HCI graduates will be poised to take on strategic roles at early stages of their careers, including Front End Engineer, Interaction Designer, Technical Product Manager and UX Engineer positions. HCI students aiming for research careers or graduate school can select a senior thesis option and conduct independent research work under the mentorship of HCI faculty.

Curriculum - B.S. in Human-Computer Interaction

The following requirements are for students entering Fall 2024.

The primary major in HCI supports students by preparing them with very strong technical knowledge, skills, and understanding. HCI majors must take a minimum of 360 units distributed as follows:

- CS Core: 5 courses + freshman immigration course
- Core @ CMU: 3 units
- Mathematics and Statistics: 4 courses
- HCI Core: 6 courses
- Psychology: 1 course
- HCI Electives: 4 courses
- HCI Capstone Project: 1 course
- Free Electives: 4 courses
- Science and Engineering: 4 courses
- Humanities and Arts (Gen Ed): 7 courses

Total: 36 courses

Computer Science Core (5 courses + immigration course)

Prerequisite Courses		Units
15-112	Fundamentals of Programming and Computer Science	12
07-131	Great Practical Ideas for Computer Scientists	2

Required Courses		Units
07-128	First Year Immigration Course	3
15-122	Principles of Imperative Computation	12
15-150	Principles of Functional Programming	12
15-151	Mathematical Foundations for Computer Science	12
15-210	Parallel and Sequential Data Structures and Algorithms	12
15-213	Introduction to Computer Systems	12

Mathematics and Statistics Core (4 courses)

Prerequisite Course		Units
21-120	Differential and Integral Calculus	10

Required Courses		
21-122	Integration and Approximation	10
21-259	Calculus in Three Dimensions	10
Select one of the following courses:		
15-259	Probability and Computing	12
21-325	Probability	9
36-218	Probability Theory for Computer Scientists	9
36-225	Introduction to Probability Theory	9
Select one of the following courses:		
15-251	Great Ideas in Theoretical Computer Science	12
21-241	Matrices and Linear Transformations	11
21-242	Matrix Theory	11
36-226	Introduction to Statistical Inference	9
36-401	Modern Regression	9

HCI Core (6 courses)

Research & Evaluation Courses (2)		Units
05-410	User-Centered Research and Evaluation	12
Select one:		
36-202	Methods for Statistics & Data Science	9
36-315	Statistical Graphics and Visualization	9
70-208	Regression Analysis	9
Ideation & Design Courses (2)		
05-360	Interaction Design Fundamentals	12
Select one:		
05-361	Advanced Interaction Design	12
05-291	Learning Media Design	12
05-315	Persuasive Design	12
05-317	Design of Artificial Intelligence Products	12
05-418	Design Educational Games	12
05-452	Service Design	12
05-470	Digital Service Innovation	12
*Some (but not all) special topics classes (05-499) might also count towards the advanced design class requirement. Please consult with an HCI undergraduate advisor.		
Technical Core (2)		
05-380	Prototyping Algorithmic Experiences	15
05-431	Software Structures for User Interfaces	12

Psychology (1 course)

Select one:		Units
85-211	Cognitive Psychology	9
85-213	Human Information Processing and Artificial Intelligence	9
85-241	Social Psychology	9
85-251	Personality	9
85-370	Perception	9
85-408	Visual Cognition	9
85-421	Language and Thought	9
88-120	Reason, Passion and Cognition	9

Note: The Psychology course fulfills the Category 1: Cognition, Choice and Behavior requirement for HCI majors.

HCI Electives (3 courses)

HCI Design Elective (1) **Select a different course from that chosen under Ideation and Design HCI core (above)		Units
05-361	Advanced Interaction Design	12
05-291	Learning Media Design	12
05-315	Persuasive Design	12
05-317	Design of Artificial Intelligence Products	12
05-418	Design Educational Games	12
05-452	Service Design	12
05-470	Digital Service Innovation	12
*Some (but not all) special topics classes (05-499) might also count towards the advanced design class requirement. Please consult with an HCI undergraduate advisor.		
HCI Technical Elective (1)		
05-318	Human AI Interaction	12
05-333	Gadgets, Sensors and Activity Recognition in HCI	12
05-434	Machine Learning in Practice	12
05-839	Interactive Data Science	12
10-315	Introduction to Machine Learning (SCS Majors)	12
11-411	Natural Language Processing	12
15-281	Artificial Intelligence: Representation and Problem Solving	12
15-365	Experimental Animation	12
15-388	Practical Data Science	9
15-462	Computer Graphics	12
15-464	Technical Animation	12
15-466	Computer Game Programming	12
15-494	Cognitive Robotics: The Future of Robot Toys	12
16-467	Introduction to Human Robot Interaction	12
17-428	Machine Learning and Sensing	12
17-437	Web Application Development	12
17-537	Artificial Intelligence Methods for Social Good	9
**The remaining (1) elective can be chosen from the above lists or from the pre-approved list of HCI electives. Other options will require approval from the program director.		

SCS Elective (1 Course)

This elective can be from any SCS department; 200-level or above, at least 9 units (see exceptions below): Computer Science [15-], Computational Biology [02-], Human Computer Interaction [05-], Machine Learning [10-], Language Technologies [11-], Robotics [16-], and Software Engineering [17-]. (NOTE: The following undergraduate courses do NOT count as Computer Science electives: 02-201, 02-223, 02-261. Some IDEATE courses and some SCS undergraduate and graduate courses might not be allowed based on course content. Consult with HCI advisor before registration to determine eligibility for this requirement.

*Students who take two intro minis from 02-180, 05-180, 07-180, and 16-180 during their first year may use these two courses together as one SCS elective.

HCI Capstone Project (1 course)

05-571	Undergraduate Project in HCI	12

Science & Engineering (4 courses)

Four courses in the domain of science and engineering are required, of which at least one must have a laboratory component and at least two must be from the same department. These courses typically come from the Mellon College of Science and the College of Engineering (CIT). Courses with a primary focus on programming, computation or mathematics are not acceptable for science or engineering courses. Requirements for this component of the degree are listed under the SCS main page under General Education Requirements.

Humanities & Arts (7 courses)

These requirements follow the SCS General Education requirements for Humanities & Arts. Requirements for this component of the degree are listed under the SCS main page under General Education Requirements. NOTE: The Psychology requirement of the HCI core will satisfy the General Education requirement for Category 1: Cognition, Choice & Behavior.

Core@CMU (1 Course)

The following course is required of all CMU students:

99-101	Core@CMU	3

Free Electives (4 courses)

A free elective is any Carnegie Mellon course. However, a maximum of 9 units of Physical Education and/or Military Science (ROTC) and/or Student-Led (StuCo) courses may be used toward fulfilling graduation requirements. These could be used for optional Research Track or an optional minor or concentration.

Additional Major in Interdisciplinary HCI

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OVERVIEW

Human-Computer Interaction (HCI) is a fast growing field devoted to the design, implementation, and evaluation of interactive computer-based technology. Examples of HCI products include intelligent computer tutors, wearable computers, social networking sites, and internet-connected personal digital assistants (PDAs). Constructing an HCI product is a cyclic, iterative process that has at least three stages: Design, Implementation, and Evaluation.

The Design stage involves principles of design and human behavior, the Implementation stage principles of computer science, and the Evaluation stage empirical research methods common to several disciplines. There are thus four topical areas to cover in this major: Human Behavior, Design, Implementation, and Evaluation. In slightly more detail, the major involves the following sorts of knowledge and skill:

Design

- Eliciting from the client, formulating, and articulating functional specifications
- Knowing how human factors and cognitive models should inform design
- Knowing the principles of, and having experience with, communication design
- Understanding how implementation constraints should inform design
- Incorporating evaluation results into iterated designs

Implementation Programming Skills

- Standard programming languages - e.g., C++, Java
- Rapid prototyping skills
- Computational literacy, i.e., knowledge sufficient for effective communication and decision making about:
    - interface construction tools and languages
    - multimedia authoring tools
    - data structures and algorithms
    - operating systems, platforms, etc.

Evaluation

- Experimental design
- Focus groups

- Surveys
- Usability testing (Cognitive walkthroughs, user models, heuristic evaluation, GOMS)
- Statistical analysis

There are over 45 courses relevant to these areas that are now offered by eight different departments in four different colleges at Carnegie Mellon (School of Computer Science, Dietrich College of Humanities and Social Sciences, College of Fine Arts, and Tepper School of Business).

ABOUT THE ADDITIONAL MAJOR

The Additional Major in Interdisciplinary Human-Computer Interaction (HCI) is available to current undergraduate students from any CMU college. Students maintain their primary major, and by adding an additional major in HCI, can explore multiple areas of study during their time at CMU. Applications to the additional major are processed once a year, in the spring (see below).

CURRICULUM

The following requirements are for students entering Fall 2024.

The Additional Major in Interdisciplinary Human-Computer Interaction (HCI) consists of 12 prerequisite and required courses.

Prerequisite Courses (4)

These courses do not need to be taken before applying to the additional major program. However, please note the required order sequence for three courses, listed below.

- Introductory statistics course, details below
- Psychology (details below) *must be completed before enrolling in the HCI core course 05-410 User-Centered Research and Evaluation*
- A freshman-level programming course (details below) *must be completed before enrolling in the HCI core course 05-430 or 05-380*
- 05-360: Interaction Design Fundamentals *must be completed before enrolling in the HCI core course 05-361 Advanced Interaction Design*

Prerequisites		Units
Psychology (Select one)		
85-211	Cognitive Psychology	9
85-241	Social Psychology	9
85-213	Human Information Processing and Artificial Intelligence	9
Design		
05-360	Interaction Design Fundamentals Design majors do not need to take 05-360 as a prerequisite, since they learn similar material in other courses for their major.	12
Statistics (Select one)		
36-200	Reasoning with Data	9
36-220	Engineering Statistics and Quality Control	9
36-225-36-226	Introduction to Probability Theory - Introduction to Statistical Inference	18
36-226	Introduction to Statistical Inference	9
70-207	Probability and Statistics for Business Applications	9
Introduction to Programming (Select one)		
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
15-121	Introduction to Data Structures	10

HCI Core Courses (4)

The HCI core courses include the following required courses: (Prerequisite courses and the electives are not core courses.)

- 05-410: User-Centered Research & Evaluation (UCRE)
- 05-361: Advanced Interaction Design or another advanced Design course (see details below)
- 05-430: Programming Usable Interfaces (PUI) or 05-380: Prototyping Algorithmic Experiences (PAX) or 05-431: Software Structures for User Interfaces (SSUI)
- 05-571: Undergraduate Project in HCI (Capstone) *The Capstone course should be taken during the student's final spring semester.

Core Courses		Units
05-410	User-Centered Research and Evaluation	12
Select one:		
05-361	Advanced Interaction Design	12
05-291	Learning Media Design	12
05-315	Persuasive Design	12
05-317	Design of Artificial Intelligence Products	12
05-418	Design Educational Games	12
05-452	Service Design	12
05-470	Digital Service Innovation	12
*Some (but not all) special topics classes (05-499) might also count towards the advanced design class requirement. Please consult with an HCI undergraduate advisor.		
Select one:		
05-430	Programming Usable Interfaces	15
05-380	Prototyping Algorithmic Experiences	15
05-431	Software Structures for User Interfaces	12
Capstone		
05-571	Undergraduate Project in HCI	12

Special Notes for Design Majors

- Design majors do not need to take 05-360 Interaction Design Fundamentals as a prerequisite, since they learn similar material in other courses for their major.

Electives (4 courses)

HCI additional major students must take four HCI-related electives (9 units or more). Electives are intended to provide additional major students with advanced concepts and skills relevant to HCI or breadth of experience not available from their primary major. Given these goals, most electives will be 300-level courses or higher. Courses at the 100-level and 200-level in one's primary major will not count as electives, although the same course taken by a non-major may count (approval is still required).

Students can take electives in the HCII or courses relevant to HCI from many other departments on campus. All external electives are approved on a case-by-case basis.

All 05-xxx courses are pre-approved as HCI electives; however, core courses cannot double count as electives. See the HCII website for a list of current pre-approved electives: https://www.hcii.cmu.edu/academics/hci-undergrad/electives (https://www.hcii.cmu.edu/academics/hci-undergrad/electives/)

Double Counting

Students may double count up to two (2) of the required core and elective courses (prerequisite courses do not apply to the double-counting rule) with their primary major.

Accelerated Master's Program (AMHCI)

The HCII currently offers a three semester (12-month), 15 course Masters in HCI. Undergraduates currently enrolled in the HCI major may apply for the Accelerated Masters program in the fall semester of their senior year. If admitted, students finish the masters degree the following fall semester. For more information, see the HCII website: https://www.hcii.cmu.edu/academics/accelerated-masters (https://www.hcii.cmu.edu/academics/accelerated-masters/)

Admission to the Additional Major

Because space is limited in the major's required courses, enrollment in the HCI additional major is currently limited. The admissions period occurs in spring semesters. For more details, see the website at hcii.cmu.edu/academics/hci-undergrad/additional-major-hci/admissions (https://www.hcii.cmu.edu/academics/hci-undergrad/additional-major-hci/admissions/).

Minor in Interdisciplinary HCI

The Minor in Interdisciplinary Human-Computer Interaction will give students core knowledge about techniques for building successful user interfaces, approaches for conceiving, refining, and evaluating interfaces that are useful and useable, and techniques for identifying opportunities for computational technology to improve the quality of people’s lives. The students will be able to effectively collaborate in the design, implementation, and evaluation of easy-to-use, desirable, and thoughtful interactive systems. They will be

- Fieldwork for understanding people’s needs and the influence of context
- Generative approaches to imagining many possible solutions such as sketching and “bodystorming”
- Iterative refinement of designs
- Basic visual design including typography, grids, color, and the use of images
- Implementation of interactive prototypes
- Evaluation techniques including discount and empirical evaluation methods

The HCI minor is targeted at undergraduates who expect to get jobs where they design and/or implement information technology-based systems for end users, as well as students with an interest in learning more about the design of socio-technical systems. It is appropriate for students with a major in Information Systems, as well as students in less software-focused majors, including Design, Architecture, Art, Business Administration, Psychology, Statistics, Decision Science, Mechanical Engineering, Electrical Engineering, English and many others in the university.

CURRICULUM

The following requirements are for students entering Fall 2024.

Prerequisite (select one)		Units
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
15-121	Introduction to Data Structures	10
15-104	Introduction to Computing for Creative Practice	10

Core Courses		Units
05-391	Designing Human Centered Software Designing Human Centered Software (DHCS)1: This course provides an overview of the most important methods taught in the Additional Major in HCI, such as Contextual Inquiry, Prototyping and Iterative Design, Heuristic Evaluation, and Think Aloud User Studies. It covers in a more abbreviated form the content of 05-410 User-Centered Research and Evaluation and 05-430 Programming Usable Interfaces. Alternatively, a student can take both 05-410 and 05-430 OR 05-380. If students take this course sequence, they get credit for fulfilling this 05-391 requirement plus one elective.	12
05-360	Interaction Design Fundamentals	12

Special Notes for Design Majors: HCI Minors who have a primary major in Design may substitute taking 05-391 Designing Human-Centered Software with another HCI 05 elective course; HCI Minors who have a primary major in Design must substitute taking 05-360 Interaction Design Fundamentals with another HCI 05-xxx course.

Electives

HCI minor students must take four HCI-related electives (9 units or more). Electives are intended to provide minor students with advanced concepts and skills relevant to HCI or breadth of experience not available from their primary major. Given these goals, most electives will be 300-level courses or higher. Courses at the 100-level and 200-level in one's primary major will not count as electives, although the same course taken by a non-major may count (approval is required).

Students can take electives in the HCII or courses relevant to HCI from many other departments on campus. All external electives are approved on a case-by-case basis.

All 05-xxx courses are pre-approved as HCI electives; however, core courses cannot double-count as electives. See the HCII website for a list of current pre-approved electives: https://www.hcii.cmu.edu/academics/hci-undergrad/electives (https://www.hcii.cmu.edu/academics/hci-undergrad/electives/)

Double Counting

Students may double count up to two (2) of the required core and elective courses (prerequisite courses do not apply to the double-counting rule) with their primary major.

Admission to the Minor

Because space is limited in the minor's required courses, enrollment in the HCI minor is currently limited. The admissions period occurs in spring semesters. For more details, see the website at https://www.hcii.cmu.edu/academics/hci-undergrad/minor-hci (https://www.hcii.cmu.edu/academics/hci-undergrad/minor-hci/).

Human-Computer Interaction Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*)each semester for course offerings and for any necessary pre-requisites or co-requisites.*

05-090 Human-Computer Interaction Practicum

All Semesters: 3 units
This course is for HCII students who wish to have an internship experience as part of their curriculum. Students are required to write a one-page summary statement prior to registration that explains how their internship connects with their HCI curriculum, specifically on how it uses material they have learned as well as prepares them for future courses. Near the end of the internship, students will be required to submit a reflection paper that describes the work they did in more detail, including lessons learned about the work experience and how they utilized their HCI education to work effectively. International students should consult with the Office of International Education for appropriate paperwork and additional requirements before registration. Units earned count toward the total required units necessary for degree completion; students should speak with an academic advisor for details. This course may be taken at most 3 times for a total of 9 units maximum. Students normally register for this course for use during the summer semester.

05-180 Introduction to Human-Computer Interaction

Spring: 5 units
This course is for first-year students who are interested in learning more about HCI, especially first-year SCS students considering the primary HCI major.

05-200 Ethics and Policy Issues in Computing

Intermittent: 9 units
Should autonomous robots make life and death decisions on their own? Should we allow them to select a target and launch weapons? To diagnose injuries and perform surgery when human doctors are not around? Who should be permitted to observe you, find out who your friends are, what you do and say with them, what you buy, and where you go? Do social media and personalized search restrict our intellectual horizons? Do we live in polarizing information bubbles, just hearing echoes of what we already know and believe? As computing technology becomes ever more pervasive and sophisticated, we are presented with an escalating barrage of decisions about who, how, when, and for what purposes technology should be used. This course will provide an intellectual framework for discussing these pressing issues of our time, as we shape the technologies that in turn shape us. We will seek insight through reading, discussion, guest lectures, and debates. Students will also undertake an analysis of a relevant issue of their choice, developing their own position, and acquiring the research skills needed to lend depth to their thinking. The course will enhance students' ability to think clearly about contentious technology choices, formulate smart positions, and support their views with winning arguments.

05-291 Learning Media Design

Fall: 12 units
[IDeATe collaborative course] Learning is a complex human phenomenon with cognitive, social and personal dimensions that need to be accounted for in the design of technology enhanced learning experiences. In this studio course students will apply learning science concepts to critique existing forms of learning media, establish a set of design precedents to guide project work and produce a series of design concepts that support learning interactions in a real-world context. Collaborating in small interdisciplinary teams, students will partner with a local informal learning organization (e.g. museum, after school program provider, maker space) to conduct learning design research studies, synthesize findings, establish learning goals and iteratively prototype and assess design concepts. As final deliverables, students will present their design research findings, design concepts, and prototypes to stakeholders, and draft a media-rich proposal for their learning media concept to pitch to a local funder. Please note that there may be usage/materials fees associated with this course. Please note that there may be usage/materials fees associated with this course.

05-292 IDeATe: Learning in Museums

Spring: 12 units
Learning in Museums brings together students from across the disciplines to consider the design of mediated learning experiences though a project-based inquiry course. Students will be introduced to a range of design research methods and associated frameworks that explore the cognitive, social and affective dimensions of learning in everyday contexts through readings, invited lectures, in-class activities and assignments. Students will conduct a series of short design research studies to define learning goals and develop supporting design concepts that improve learning outcomes for diverse participants in informal learning settings (e.g. museums, after school programs, maker spaces or online). In concept development, we will look at how to position technology and question its role in the setting to engage and foster positive learning interactions. This course will culminate in a media-rich presentation of design concepts and a prototype to a stakeholder audience, and include an evaluation plan describing how learning outcomes for the project would be assessed.

05-300 HCI Undergraduate Pro Seminar

All Semesters: 2 units
HCI is a broad field that brings together approaches from design, computer science, and psychology. This course provides an introduction to the field of HCI and to the HCI community at CMU. Guest speakers from around campus will provide a general introduction to these approaches and how they are pursued at CMU, and will describe research opportunities that are available to undergraduates. The course will also discuss career options in both industry and academia for students of HCI, and will include presentations from HCI alumni and sessions on preparing resumes, creating portfolios, and interviewing for jobs. The course is designed for current or potential HCI majors and minors but is open to anyone with an interest in applying for the HCI major/minor.

Course Website: https://hcii.cmu.edu/academics/courses (https://hcii.cmu.edu/academics/courses/)

05-315 Persuasive Design

Fall: 12 units
This project-based course focuses on the ethical, human-centered design and evaluation of persuasive technologies that aim to change users' attitudes, emotions, or behaviors in ways that benefit the self and/or society. In addition to exposing students to an array of psychological theories and strategies for implicit and explicit persuasion, the course will cover a variety of topics illustrating both the pitfalls and possibilities in designing for positive impact in HCI. The focal point of the class will be the semester project, for which student teams will iteratively conceptualize, prototype, implement, and evaluate a tool, system, or change to a ubiquitous computing environment that intends to stimulate and sustain belief or behavior change (such as reducing cognitive or social biases, building healthy or prosocial habits, or resisting other persuasive forces one encounters on a daily basis).

05-317 Design of Artificial Intelligence Products

Intermittent: 12 units
This course teaches students how to design new products and services that leverage the capabilities of AI and machine learning to improve the quality of peoples lives. Students will learn to follow a matchmaking design, user-centered design, and service design process. Students will learn to ideate; reframing problematic situations by envisioning many possible products and services. Students will learn to iteratively refine and assess their ideas with real users/customers. Class projects will focus on the challenges of deploying systems that generate errors and the challenges of situating intelligent systems such that they harmonize the best qualities of human and machine intelligence.

Course Website: https://hcii.cmu.edu/academics/courses (https://hcii.cmu.edu/academics/courses/)

05-318 Human AI Interaction

Intermittent: 12 units
Artificial Intelligence is inspired by human intelligence, made powerful by human data, and ultimately only useful in how it positively affects the human experience. This course is an introduction to harnessing the power of AI so that it is beneficial and useful to people. We will cover a number of general topics: agency and initiative, AI and ethics, bias and transparency, confidence and errors, human augmentation and amplification, trust and explainability, mixed-initiative systems, and programming by example. These topics will be explored via projects in dialog and speech-controlled systems, automatic speech recognition, computer vision, data science, recommender systems, text summarization, learning science, UI personalization, and visualization. Students will complete individual weekly mini-projects in which they will design and build AI systems across a wide variety of domains. Students should be comfortable with programming; assignments will be primarily in Python and Javascript. Prior experience with AI/machine learning will be useful but is not required. Students will also be responsible for weekly readings and occasional presentations to the class.

Course Website: http://www.hcii.cmu.edu/academics/courses (http://www.hcii.cmu.edu/academics/courses/)

05-319 Data Visualization

Fall: 12 units
This course is an introduction to key design principles and techniques for interactively visualizing data. The major goals of this course are to understand how visual representations can help in the analysis and understanding of complex data, how to design effective visualizations, and how to create your own interactive visualizations using modern web-based frameworks.

Course Website: https://dig.cmu.edu/courses/2022-fall-datavis.html

05-320 Social Web

Intermittent: 12 units
With the growth of online environments like MySpace, Second Life, World of Warcraft, Wikipedia, blogs, online support groups, and open source development communities, the web is no longer just about information. This course, jointly taught by a computer scientist and a behavioral scientist, will examine a sampling of the social, technical and business challenges social web sites must solve to be successful, teach students how to use high-level tools to analyze, design or build online communities, and help them understand the social impact of spending at least part of their lives online. This class is open to advanced undergraduates and graduate students with either technical or non-technical backgrounds. Course work will include lectures and class discussion, homework, class presentations, and a group research or design project.

05-321 Transformational Game Design Studio

Fall: 12 units
TBA

05-333 Gadgets, Sensors and Activity Recognition in HCI

Fall: 12 units
Recent advances in HCI have been driven by new capabilities to deliver inexpensive devices to users, to display information in mobile and other contexts, to sense the user and their environment, and use these sensors to create models of a user's context and actions. This course will consider both concepts surrounding these new technological opportunities through discussion of current literature - and practical considerations the skills needed to actually build devices. About 1/3 of this class will review current advances in this area. The remainder will be devoted to development of individual skills so that students leaving the class will have an ability to actually build small devices for human interaction (in short: "HCI gadgets"). In particular, the course will concentrate on the basics of building simple microcontroller-based devices and will also provide very basic coverage of the machine learning techniques needed for simple sensor-driven statistical models. The course is designed to be accessible to students with a wide range of backgrounds including both technically-oriented and non-technical students (especially Designers) interested in HCI. The class will be project oriented with 4-5 electronic prototype building projects during the semester. At least two of these projects will be self-defined in nature and can be adapted to the existing skills and interests of each student. There are no formal prerequisites for this class. However, the class will involve programming and debugging of micro-controllers. Some coverage of the language used to do this will be provided, and if required by your background, the programming component of the projects can be made comparatively small (but, in that case some other aspect of the projects will need to be expanded). However, you should not take this course if you have no programming background. This course assumes no background in electronics.

Course Website: http://www.hcii.cmu.edu/courses/applied-gadgets-sensors-and-activity-recognition-hci (http://www.hcii.cmu.edu/courses/applied-gadgets-sensors-and-activity-recognition-hci/)

05-341 Organizational Communication

All Semesters: 9 units
Most of management is communication. You communicate to get information that will be the basis of decisions, coordinate activity, to provide a vision for the people who work for and with you, to and to sell yourself and your work. The goal of this course is to identify communication challenges within work groups and organizations and ways to overcome them. To do this requires that we know how communication normally works, what parts are difficult, and how to fix it when it goes wrong. The focus of this course is on providing you with a broad understanding of the way communication operates within dyads, work groups, and organizations. The intent is to give you theoretical and empirical underpinnings for the communication you will undoubtedly participate in when you move to a work environment, and strategies for improving communication within your groups. Because technology is changing communication patterns and outcomes both in organizations and more broadly in society, the course examines these technological changes. Readings come primarily from the empirical research literature.

Course Website: http://www.hcii.cmu.edu/courses/organizational-communication (http://www.hcii.cmu.edu/courses/organizational-communication/)

05-360 Interaction Design Fundamentals

Fall and Spring: 12 units
IXD Fundamentals introduces the human-centered design process as well as fundamental interaction design principles, methods, and practices. The course is for both students who may only enroll in one interaction design course and those who intend to build upon their HCI learning by taking advanced interaction design courses. Students must work effectively as individuals and in small teams to learn interaction design concepts and apply them to real-world problems. By the end of this course students should be able to; -Apply appropriate interaction design methods in a human-centered design process. -Create persuasive interim and final design artifacts that demonstrate communication design fundamentals. -Facilitate productive and structured critique across the class and with instructors. -Explain and apply fundamental interaction design principles. -Create clarity and readability in artifacts, including GUIs and deliverables, through the disciplined application of visual design principles such as typography, color and composition. -Practice reframing a given problem in order to create opportunities that drive generating multiple solutions. -Demonstrate habits that foster the creative process, including drawing, divergent thinking, and creative experimentation. -Identify and explore with interaction design materials. This course serves as a prerequisite for Advanced Interaction Design Studio (number TBD). Students who are required to take this course have priority and will be enrolled first. No coding is required.

05-361 Advanced Interaction Design

Spring: 12 units
Advanced Interaction Design follows Interaction Design for Human-Computer Interaction (05-360/05-660). Students are expected to build on the basic interaction design principles they learned in Interaction Design Fundamentals by applying advanced methods to solve more complex problems using emerging technologies in user experiences that cross devices, modalities and contexts. Students learn how to design with advanced technologies that predict, assist and automate, and make through a design system. Systems thinking, data as a design material, and UI design are emphasized in projects which are designed to give students experience solving complex problems that they are likely to encounter as practitioners. Advanced Interaction Design prepares students to become interaction designers that take a rigorous and principled approach to solving enterprise-scale problems where many systems and applications serve many stakeholders.
Prerequisites: 05-392 or 05-651 or 05-360

05-380 Prototyping Algorithmic Experiences

Intermittent: 15 units
This project-based course provides an overview and hands-on introduction to iterative prototyping methods in HCI, with an emphasis on current and emerging technologies such as data-driven algorithmic systems, AI and machine learning, spatial computing, and IoT. Students will learn and implement approaches for creating and using prototypes to iteratively inform the creation of new technologies. The course will help students learn to strategically evaluate whether a given prototyping approach is a good fit for a given design or research question. In addition to HCI undergraduate majors, the course is open to undergraduate and graduate level students with proficiency in programming and prior courses or experience in user-centered research, design, and/or evaluation. Some exceptions to the course prerequisites will be granted with permission of the instructor.
Prerequisites: 15-112 and (15-121 or 15-122 or 15-150 or 15-210) and (05-650 or 05-651 or 05-391 or 05-410 or 05-392 or 05-470 or 05-317 or 05-360 or 05-452)

05-391 Designing Human Centered Software

All Semesters: 12 units
"Why are things so hard to use these days? Why doesn't this thing I just bought work? Why is this web site so hard to use? These are frustrations that we have all faced from systems not designed with people in mind.
The question this course will focus on is: how can we design human-centered systems that people find useful and usable? This course is a broad introduction to designing, prototyping, and evaluating user interfaces.
If you take only one course in Human-Computer Interaction, this is the course for you. We will cover theory as well as practical application of ideas from Human-Computer Interaction. Coursework includes lectures, class discussion, homework, class presentations, and group projects. This class is open to all undergrads and grad students, with either technical or non-technical majors. However, there is a programming prerequisite. "
Prerequisites: 15-112 or 15-110 or 15-122 or 15-104

Course Website: http://www.hcii.cmu.edu/courses/designing-human-centered-software (http://www.hcii.cmu.edu/courses/designing-human-centered-software/)

05-392 Interaction Design Overview

Fall: 9 units
This studio course offers a broad overview of communication and interaction design. Students will learn design methodologies such as brainstorming, sketching, storyboarding, wire framing, and prototyping. Students learn to take a human-centered design approach to their work. Assignments include short in-class exercises as well as individual and team-based projects. Students take part in studio critiques, engaging in critical discussions about the strengths and weaknesses of their own work and the work of others. No coding is required. When registering for this course, undergraduate students are automatically placed the wait list.

05-395 Applications of Cognitive Science

Spring: 9 units
The goal of this course is to examine cases where basic research on cognitive science, including cognitive neuroscience, has made its way into application, in order to understand how science gets applied more generally. The course focuses on applications that are sufficiently advanced as to have made an impact outside of the research field per se; for example, as a product, a change in practice, or a legal statute. Examples are virtual reality (in vision, hearing, and touch), cognitive tutors, phonologically based reading programs, latent semantic analysis applications to writing assessment, and measures of consumers' implicit attitudes. The course will use a case-study approach that considers a set of applications in detail, while building a general understanding of what it means to move research into the applied setting. The questions to be considered include: What makes a body of theoretically based research applicable? What is the pathway from laboratory to practice? What are the barriers - economic, legal, entrenched belief or practice? The format will emphasize analysis and discussion by students. They should bring to the course an interest in application; extensive prior experience in cognitive science is not necessary. The course will include tutorials on basic topics in cognitive science such as perception, memory, and spatial cognition. These should provide sufficient grounding to discuss the applications.

Course Website: http://www.hcii.cmu.edu/courses/applications-cognitive-science (http://www.hcii.cmu.edu/courses/applications-cognitive-science/)

05-410 User-Centered Research and Evaluation

Fall: 12 units
This course provides an overview and introduction to the field of human-computer interaction (HCI). It introduces students to tools, techniques, and sources of information about HCI and provides a systematic approach to design. The course increases awareness of good and bad design through observation of existing technology and teaches the basic skills of generative and evaluative research methods. This is a companion course to courses in visual design (51-422) and software implementation (05-430, 05-431). When registering for this course, undergraduate students are automatically placed the wait list. Students will be then moved into the class, based on if they are in the BHCI second major and year in school e.g. seniors, juniors, etc.
In the Fall, this course is NOT open to students outside the HCI major. The Spring offering is open to all students. This course is a core requirement for students in the HCI additional major.
Prerequisites: 85-421 or 85-408 or 85-370 or 85-251 or 85-213 or 85-211 or 85-241 or 88-120

05-413 Human Factors

Fall: 9 units
This course uses theory and research from human factors, cognitive science, and social science to understand and design the interactions of humans with the built world, tools, and technology. The course emphasizes current work in applied domains such as automotive design, house construction, medical human factors, and design of information devices. The course also will emphasize not only individual human factors (e.g., visual response, anthropometry) but also the organizational arrangements that can amplify or correct human factors problems. Through reading, discussion, and projects, you will learn about human perceptual, cognitive, and physical processes that affect how people interact with, and use, technology and tools. You will learn why we have so many automobile accidents, voting irregularities, and injuries from prescription medication. You will learn some tried and true solutions for human factors problems, and some of the many problems in human factors that remain. You will also have gained experience in research in this field.

Course Website: http://www.hcii.cs.cmu.edu

05-417 Computer-mediated Communication

Spring: 6 units
This course examines fundamental aspects of interpersonal communication and considers how different types of computer-mediated communications (CMC) technologies affect communication processes. Among the topics we will consider are: conversational structure and CMC, tools to support nonverbal and paralinguistic aspects of communication such as gesture and eye gaze, and social and cultural dimensions of CMC. Students will be expected to post to weekly discussion lists, to write a paper on a specific aspect of CMC, and to present a talk on their final project to the class. The course should be appropriate for graduate students in all areas and for advanced undergraduates.

05-418 Design Educational Games

Spring: 12 units
The potential of digital games to improve education is enormous. However, it is a significant challenge to create a game that is both fun and educational. In this course, students will learn to meet this challenge by combining processes and principles from game design and instructional design. Students will also learn to evaluate their games for fun, learning, and the integration of the two. They will be guided by the EDGE framework for the analysis and design educational games. The course will involve a significant hands-on portion, in which students learn a design process to create educational games digital or non-digital. They will also read about existing educational games and discuss game design, instructional design, learning and transfer, and the educational effectiveness of digital games. They will analyze an educational game and present their analysis to the class.

Course Website: https://www.hcii.cmu.edu/course/design-of-educational-games (https://www.hcii.cmu.edu/course/design-of-educational-games/)

05-430 Programming Usable Interfaces

Spring: 15 units
This course is combines lecture, and an intensive programming lab and design studio. It is for those who want to express their interactive ideas in working prototypes. It will cover the importance of human-computer interaction/interface design, iterative design, input/output techniques, how to design and evaluate interfaces, and research topics that will impact user interfaces in the future. In lab, you will learn how to design and program effective graphical user interfaces, and how to perform user tests. We will cover a number of prototyping tools and require prototypes to be constructed in each, ranging from animated mock-ups to fully functional programs. Assignments will require implementing UIs, testing that interface with users, and then modifying the interface based on findings. Some class sessions will feature design reviews of student work. This course is for HCII Masters students and HCI dual majors with a minimal programming background. Students will often not be professional programmers, but will need to interact with programmers. RECITATION SELECTION: Students taking this course can sign up for either Prototyping Lab recitation. PREREQUISITES: Proficiency in a programming language, program structure, algorithm analysis, and data abstraction. Normally met through an introductory programming course using C, C++, Pascal or Java, such as 15100, 15112, 15127 or equivalent. Students entering this course should be able to independently write a 300-line program in 48 hours. This course is NOT open to students outside of the BHCI program.
Prerequisites: 15-110 or 15-104 or 15-112 or 15-127 or 15-100

05-431 Software Structures for User Interfaces

Fall: 12 units
This course considers the basic and detailed concepts for building software to implement user interfaces (UIs). It considers factors of input, output, application interface, and related infrastructure as well as the typical patterns used to implement them. It considers how these aspects are organized and managed within a well-structured object oriented system. We will cover a variety of "front-end" programming contexts, including conventional graphical user interface (GUI) programming for mobile apps (phones, watches), web apps, and regular desktop applications, across a variety of frameworks. We will also cover programming for data-driven and conversational (AI) user interfaces. We will briefly touch on front-end programming for visualizations, games, 3D, and virtual and artificial reality (VR and AR), along with interactive UI tools such as prototypers and resource editors. The homeworks and project in this course will involve extensive object-oriented programming, likely in both Java and JavaScript, so this course is only appropriate for students with a strong programming background. Note that this is not an HCI methods course and #8212; we do not cover user-centered design or evaluation methods. This course is designed for students in the SCS HCI undergrad Major, but it also available to any undergrad or graduate student with an interest in the topic and solid prior programming experience who wish to understand the structures needed for professional development of interactive systems. Note that all students who register for this class will initially be placed on a waitlist. Priority for getting into the class are students in the HCII programs (more senior students first), and then others. The graduate (05-631) and undergraduate (05-431) numbers are for the same course with the same work.
Prerequisites: 17-437 or 17-514 or 17-214 or 15-214 or 15-213 or 18-213 or 15-513 or 14-513

05-432 Personalized Online Learning

Fall: 12 units
Online learning has become widespread (e.g., MOOCs, online and blended courses, and Khan Academy) and many claim it will revolutionize higher education and K-12. How can we make sure online learning is maximally effective? Learners differ along many dimensions and they change over time. Therefore, advanced learning technologies must adapt to learners to provide individualized learning experiences. This course covers a number of proven personalization techniques used in advanced learning technologies. One of the techniques is the use of cognitive modeling to personalize practice of complex cognitive skills in intelligent tutoring systems. This approach, developed at CMU, may well be the most significant application of cognitive science in education and is commercially successful. We will also survey newer techniques, such as personalizing based on student meta-cognition, affect, and motivation. Finally, we will look at personalization approaches that are widely believed to be effective but have not proven to be so. The course involves readings and discussion of different ways of personalizing instruction, with an emphasis on cognitive modeling approaches. Students will learn to use the Cognitive Tutor Authoring Tools (CTAT) to implement tutor prototypes that rely on computer-executable models of human problem solving to personalize instruction. The course is meant for graduate or advanced undergraduate students in Human-Computer Interaction, Psychology, Computer Science, Design, or related fields, who are interested in educational applications. Students should either have some programming skills or experience in the cognitive psychology of human problem solving, or experience with instructional design.

Course Website: http://www.hcii.cmu.edu/courses/personalized-online-learning (http://www.hcii.cmu.edu/courses/personalized-online-learning/)

05-433 Programming Usable Interfaces OR Software Structures for Usable Interfaces

Fall: 6 units
Section A: Programming Usable Interfaces Section B: Software Structures for Usable Interfaces This is a lecture-only course (see 05-430/05-630 or 05-431/631 for the lecture + lab version of these courses) that is intended for those who want to learn how to design and evaluate user interfaces. We will cover the importance of human-computer interaction and interface design, the iterative design cycle used in HCI, an overview of input and output techniques, how to design and evaluate interaction techniques, and end with a discussion of hot topics in research that will impact user interfaces in the coming years. This course is only intended for HCII Masters students or HCI undergraduate majors who have already taken an associated User Interface lab, or non-MHCI/BHCI students interested in the design of user interfaces. WAITLIST LOGISTICS: Note that ALL students who register for this class will initially be placed on a waitlist. Your position on the waitlist is not an indication of whether you will be accepted into the class. Contacting the instructor will not move you off the waitlist. Priority for getting off the waitlist are MHCI students, BHCI students (more senior students first), and then others.

05-434 Machine Learning in Practice

Fall and Spring: 12 units
Machine Learning is concerned with computer programs that enable the behavior of a computer to be learned from examples or experience rather than dictated through rules written by hand. It has practical value in many application areas of computer science such as on-line communities and digital libraries. This class is meant to teach the practical side of machine learning for applications, such as mining newsgroup data or building adaptive user interfaces. The emphasis will be on learning the process of applying machine learning effectively to a variety of problems rather than emphasizing an understanding of the theory behind what makes machine learning work. This course does not assume any prior exposure to machine learning theory or practice. In the first 2/3 of the course, we will cover a wide range of learning algorithms that can be applied to a variety of problems. In particular, we will cover topics such as decision trees, rule based classification, support vector machines, Bayesian networks, and clustering. In the final third of the class, we will go into more depth on one application area, namely the application of machine learning to problems involving text processing, such as information retrieval or text categorization. 05-834 is the HCII graduate section. If you are an LTI student, please sign up for the LTI graduate course number (11-663) ONLY to count properly towards your degree requirements. 05-434 is the HCII undergraduate section. If you are an LTI student, please sign up for the LTI undergraduate course number (11-344) ONLY to count properly towards your degree requirements.

Course Website: http://www.hcii.cmu.edu/courses/applied-machine-learning (http://www.hcii.cmu.edu/courses/applied-machine-learning/)

05-435 Applied Fabrication for HCI

Fall: 12 units
This course will consider how new fabrication techniques such as 3D printing, laser cutting, CNC machining and related computer controlled technologies can be applied to problems in Human-Computer Interaction. Each offering will concentrate on a particular application domain for its projects. This year the course will consider assistive technology. This course will be very hands-on and skills-oriented, with the goal of teaching students the skills necessary to apply these technologies to HCI problems such as rapid prototyping of new device concepts. To this end? Every student in this course will build and take home a 3D printer. (There will be $400-$500 cost associated with this course to make that possible. Details on this are still to be determined.)

05-436 Usable Privacy and Security

Spring: 9 units
There is growing recognition that technology alone will not provide all of the solutions to security and privacy problems. Human factors play an important role in these areas, and it is important for security and privacy experts to have an understanding of how people will interact with the systems they develop. This course is designed to introduce students to a variety of usability and user interface problems related to privacy and security and to give them experience in designing studies aimed at helping to evaluate usability issues in security and privacy systems. The course is suitable both for students interested in privacy and security who would like to learn more about usability, as well as for students interested in usability who would like to learn more about security and privacy. Much of the course will be taught in a graduate seminar style in which all students will be expected to do a weekly reading assignment and each week different students will prepare a presentation for the class. Students will also work on a group project throughout the semester. The course is open to all graduate students who have technical backgrounds. The 12-unit course numbers (08-734 and 5-836) are for PhD students and masters students. Students enrolled in these course numbers will be expected to play a leadership role in a group project that produces a paper suitable for publication. The 9-unit 500-level course numbers (08-534 and 05-436) are for juniors, seniors, and masters students. Students enrolled in these course numbers will have less demanding project and presentation requirements.

Course Website: http://www.hcii.cmu.edu/courses/usuable-privacy-and-security (http://www.hcii.cmu.edu/courses/usuable-privacy-and-security/)

05-439 The Big Data Pipeline: Collecting and Using Big Data for Interactive Systems

Spring: 12 units
This course covers techniques and technologies for creating data driven interfaces. You will learn about the entire data pipeline from sensing to cleaning data to different forms of analysis and computation.

Course Website: http://data.cmubi.org

05-440 Interaction Techniques

Intermittent: 12 units
This course will provide a comprehensive study of the many ways to interact with computers and computerized devices. An "interaction technique" starts when the user does something that causes an electronic device to respond and includes the direct feedback from the device to the user. Examples include physical buttons and switches, on-screen menus and scroll bars operated by a mouse, touch screen widgets and gestures such as flick-to-scroll, text entry on computers or touch screens, game controllers, interactions in 3D and virtual/augmented reality, consumer electronic controls such as remote controls, and adaptations of all of these for people with disabilities. We will start with a history of the invention and development of these techniques, discuss the various options used today, and continue on to the future with the latest research on interaction techniques presented at conferences such as ACM CHI and UIST. Appropriate design and evaluation methods for interaction techniques will also be covered. Guest lectures from inventors of interaction techniques are planned. Students will have a choice for final projects that can focus on historical or novel interaction techniques.

Course Website: http://www.cs.cmu.edu/~bam/uicourse/05440inter/

05-452 Service Design

Fall: 12 units
In this course, we will collectively define and study services and product service systems, and learn the basics of designing them. We will do this through lectures, studio projects, and verbal and written exposition. Classwork will be done individually and in teams.

05-470 Digital Service Innovation

Intermittent: 12 units
Attention entrepreneurs, designers, and engineers! This course teaches you to invent digital services. You will learn about value-creation in the service sector and a human-centered design process including brainstorming, story-boarding, interviewing, video sketches, and pitching. Students work in small, interdisciplinary teams to discover unmet needs of users. They conceive of a digital service and assess its technical feasibility, financial viability, and desirability. Then they produce a plan with a business model and a video sketch and pitch it to industry professionals. Grades will be determined primarily by the quality of the team's products.

Course Website: https://www.hcii.cmu.edu/course/digital-service-innovation (https://www.hcii.cmu.edu/course/digital-service-innovation/)

05-499 Special Topics in HCI

Fall and Spring: 12 units
Special Topics in HCI is an opportunity for students interested in HCI to gain a deeper understanding of a specific area in this field. Each class is designed to cover an emerging research area within HCI, from designing large-scale peer learning systems to designing games around audience agency. All sections will help students: (1) build a more comprehensive understanding of an area of study within HCI, (2) work closely with faculty and peers to create mini-projects or team assignments that help students master the course material, (3) explore evidence-based research methods and techniques in HCI. Sections will vary in topic and often change from semester to semester. Because of this, students can take multiple sections, as they are individual classes. Undergraduate sections are listed as 499 and graduate sections are listed as 899. For descriptions of specific sections for this academic year, visit the "Courses" section on the Human-Computer Interaction Institute website.

Course Website: http://www.hcii.cmu.edu/academics/courses (http://www.hcii.cmu.edu/academics/courses/)

05-540 Rapid Prototyping of Computer Systems

Spring: 12 units
This is a project-oriented course, which will deal with all four aspects of project development: the application, the artifact, the computer-aided design environment, and the physical prototyping facilities. The class consists of students from different disciplines who must synthesize and implement a system in a short period of time. Upon completion of this course the student will be able to: generate systems specifications from a perceived need; partition functionality between hardware and software; produce interface specifications for a system composed of numerous subsystems; use computer-aided development tools; fabricate, integrate, and debug a hardware/software system; and evaluate the system in the context of an end user application. The class consists of students from different disciplines who must synthesize and implement a system in a short period of time.

Course Website: http://www.hcii.cmu.edu/courses/rapid-prototyping-computer-systems (http://www.hcii.cmu.edu/courses/rapid-prototyping-computer-systems/)

05-571 Undergraduate Project in HCI

Spring: 12 units
Experiential learning is a key component of the MHCI program. Through a substantial team project, students apply classroom knowledge in analysis and evaluation, implementation and design, and develop skills working in multidisciplinary teams. Student teams work with Carnegie Mellon University-based clients or external clients to iteratively design, build and test a software application which people directly use.
Prerequisites: 05-631 Min. grade B or 05-410 Min. grade B or 05-430 Min. grade B or 05-431 Min. grade B or 05-610 Min. grade B or 05-630 Min. grade B

Course Website: http://www.hcii.cmu.edu/courses/undergraduate-project-hci (http://www.hcii.cmu.edu/courses/undergraduate-project-hci/)

05-589 Independent Study in HCI-UG

All Semesters
In collaboration with and with the permission of the professor, undergraduate students may engage in independent project work on any number of research projects sponsored by faculty. Students must complete an Independent Study Proposal, negotiate the number of units to be earned, complete a contract, and present a tangible deliverable. The Undergraduate Program Advisor's signature is required for HCI undergraduate-level Independent Study courses. Registration is through the HCII Undergraduate Programs Manager only.

05-600 HCI Pro Seminar

Fall: 6 units
This course is only for MHCI students. This course is specifically built to expose students to the world of HCI through research and industry talks, as well as strengthening HCI communication skills for work in industry. Seminar Component:To expose students to the world of HCI through research and industry expert talks with written assignments. Conflict Management Component:To educate students on conflict management, teamwork, active listening skills, and communication skills in order to give them tools to collaborate and work more efficiently on multi-disciplinary teams. Professional Series Component: To expose students to the world of HCI through guest speakers, prepare students to navigate job hunting through resume and portfolio workshops and to provide industry insights into HCI and the profession through guest speakers and panel discussions.

Course Website: http://www.hcii.cs.cmu.edu

05-602 IDeATe: Learning in Museums

Spring: 12 units
Learning in Museums brings together students from across the disciplines to consider the design of mediated learning experiences in a project-based inquiry course. Students will be introduced to a range of design research methods and associated frameworks that explore the cognitive, social and affective dimensions of learning in everyday contexts through readings, invited lectures, in-class activities and assignments. Students will conduct a series of short design research studies to define learning goals and develop supporting design concepts intended to improve learning outcomes for diverse participants in informal learning settings (e.g. museums, after-school programs, maker spaces or online). In concept development, we will look at how to position technology and question its role in the setting to engage and foster positive learning interactions and conversation. This semester we will be working with the Carnegie Museum of Natural History as our primary stakeholder. The course will culminate in a media-rich presentation of design concepts and a fielded prototype to a review panel and include a piloted evaluation plan describing how learning outcomes for the project would be assessed. In consultation with the instructor, students in the graduate section of the course will be assigned an HCI/learning research literature review and presentation related to their project topic.

05-610 User-Centered Research and Evaluation

Fall: 12 units
This course provides and overview and introduction to the field of human-computer interaction (HCI). It introduces students to tools, techniques, and sources of information about HCI and provides a systematic approach to design. The course increases awareness of good and bad design through observation of existing technology, and teaches the basic skills of generative and evaluative research methods. This is a companion course to software implementation (05-430, 05-431 05-380). When registering for this course, undergraduate students are automatically placed the wait list. Students will be then moved into the class, based on if they are in the BHCI primary or second major and year in school e.g. seniors, juniors, etc. Freshman are not permitted to register in this course. In the Fall, this course is NOT open to students outside the HCI major or MHCI. The Spring offering is open to all students. This course is a core requirement for students in the HCI additional major and the MHCI program.
Prerequisites: 85-213 or 85-211 or 85-241 or 88-120 or 85-370 or 85-408 or 85-421 or 85-251

Course Website: http://www.hcii.cs.cmu.edu

05-615 Persuasive Design

Fall: 12 units
This project-based course focuses on the ethical, human-centered design and evaluation of persuasive technologies that aim to change users' attitudes, emotions, or behaviors in ways that benefit the self and/or society. In addition to exposing students to an array of psychological theories and strategies for implicit and explicit persuasion, the course will cover a variety of topics illustrating both the pitfalls and possibilities in designing for positive impact in HCI. The focal point of the class will be the semester project, for which student teams will iteratively conceptualize, prototype, implement, and evaluate a tool, system, or change to a ubiquitous computing environment that intends to stimulate and sustain belief or behavior change (such as reducing cognitive or social biases, building healthy or prosocial habits, or resisting other persuasive forces one encounters on a daily basis).

05-618 Human AI Interaction

Intermittent: 12 units
Artificial Intelligence is inspired by human intelligence, made powerful by human data, and ultimately only useful in how it positively affects the human experience. This course is an introduction to harnessing the power of AI so that it is beneficial and useful to people. We will cover a number of general topics: agency and initiative, AI and ethics, bias and transparency, confidence and errors, human augmentation and amplification, trust and explainability, mixed-initiative systems, and programming by example. These topics will be explored via projects in dialog and speech-controlled systems, automatic speech recognition, computer vision, data science, recommender systems, text summarization, learning science, UI personalization, and visualization. Students will complete individual weekly mini-projects in which they will design and build AI systems across a wide variety of domains. Students should be comfortable with programming; assignments will be primarily in Python and Javascript. Prior experience with AI/machine learning will be useful but is not required. Students will also be responsible for weekly readings and occasional presentations to the class.

Course Website: https://www.hcii.cmu.edu/academics/courses (https://www.hcii.cmu.edu/academics/courses/)

05-619 Data Visualization

Fall: 12 units
This course is an introduction to key design principles and techniques for interactively visualizing data. The major goals of this course are to understand how visual representations can help in the analysis and understanding of complex data, how to design effective visualizations, and how to create your own interactive visualizations using modern web-based frameworks.

Course Website: https://dig.cmu.edu/courses/2022-fall-datavis.html

05-650 Interaction Design Studio II

Spring: 12 units
This course follows Interaction Design Fundamentals (05-651). Students are expected to apply what they have learned about design thinking and methodologies as a starting point for all assignments. Students will work in teams to perform guerrilla research, synthesize data, and consider the needs of multiple stakeholders in their design of mobile services and other intelligent systems. Design concepts go beyond user interfaces to include sensors, controls, and ubiquitous computing. Emphasis is placed on the quality of the students ideas and their ability to give form to their design concepts. By completing and presenting their work, students will gain skills related to professional UX design practice.
Prerequisite: 05-651

Course Website: http://www.hcii.cmu.edu/courses/interaction-design-studio (http://www.hcii.cmu.edu/courses/interaction-design-studio/)

05-651 Interaction Design Studio 1

Fall: 12 units
This studio course introduces students to design thinking and the basic practices of interaction design. We follow a human-centered design process that includes research, concept generation, prototyping, and refinement. Students must work effectively as individuals and in small teams to design mobile information systems and other interactive experiences. Assignments approach design on three levels: specific user interactions, contexts of use, and larger systems. Students will become familiar with design methodologies such as sketching, storyboarding, wire framing, prototyping, etc. No coding is required. This course serves as a prerequisite for Interaction Design Studio (05-650). Students who are required to take this course have priority and will be enrolled first.

05-660 Interaction Design Fundamentals

Fall and Spring: 12 units
IXD Fundamentals introduces the human-centered design process as well as fundamental interaction design principles, methods, and practices. The course is for both students who may only enroll in one interaction design course and those who intend to build upon their HCI learning by taking advanced interaction design courses. Students must work effectively as individuals and in small teams to learn interaction design concepts and apply them to real-world problems. By the end of this course students should be able to; -Apply appropriate interaction design methods in a human-centered design process. -Create persuasive interim and final design artifacts that demonstrate communication design fundamentals. -Facilitate productive and structured critique across the class and with instructors. -Explain and apply fundamental interaction design principles. -Create clarity and readability in artifacts, including GUIs and deliverables, through the disciplined application of visual design principles such as typography, color and composition. -Practice reframing a given problem in order to create opportunities that drive generating multiple solutions. -Demonstrate habits that foster the creative process, including drawing, divergent thinking, and creative experimentation. -Identify and explore with interaction design materials. This course serves as a prerequisite for Advanced Interaction Design Studio (number TBD). Students who are required to take this course have priority and will be enrolled first. No coding is required.

05-661 Advanced Interaction Design

Spring: 12 units
Advanced Interaction Design (05-361/05-661) follows Interaction Design for Human-Computer Interaction (05-360/05-660). Students are expected to build on the basic interaction design principles they learned in Interaction Design Fundamentals by applying advanced methods to solve more complex problems using emerging technologies in user experiences that cross devices, modalities and contexts. Students learn how to design with advanced technologies that predict, assist and automate, and make through a design system. Systems thinking, data as a design material, and UI design are emphasized in projects which are designed to give students experience solving complex problems that they are likely to encounter as practitioners. Advanced Interaction Design prepares students to become interaction designers that take a rigorous and principled approach to solving enterprise-scale problems where many systems and applications serve many stakeholders.
Prerequisites: 05-651 or 05-692 or 05-660

05-670 Digital Service Innovation

Fall: 12 units
Attention entrepreneurs, designers, and engineers! This course teaches you to invent digital services. You will learn about value-creation in the service sector and a human-centered design process including brainstorming, storyboarding, interviewing, video sketches, and pitching. Students work in small, interdisciplinary teams to discover unmet needs of users. They conceive of a digital service and assess its technical feasibility, financial viability, and desirability. Then they produce a plan with a business model and a video sketch and pitch it to industry professionals. Grades will be determined primarily by the quality of the team's products.

Course Website: https://www.hcii.cmu.edu/course/digital-service-innovation (https://www.hcii.cmu.edu/course/digital-service-innovation/)

05-674 Ethics and Policy Issues in Computing

Intermittent: 9 units
Should autonomous robots make life and death decisions on their own? Should we allow them to select a target and launch weapons? To diagnose injuries and perform surgery when human doctors are not around? Who should be permitted to observe you, find out who your friends are, what you do and say with them, what you buy, and where you go? Do social media and personalized search restrict our intellectual horizons? Do we live in polarizing information bubbles, just hearing echoes of what we already know and believe? As computing technology becomes ever more pervasive and sophisticated, we are presented with an escalating barrage of decisions about who, how, when, and for what purposes technology should be used. This course will provide an intellectual framework for discussing these pressing issues of our time, as we shape the technologies that in turn shape us. We will seek insight through reading, discussion, guest lectures, and debates. Students will also undertake an analysis of a relevant issue of their choice, developing their own position, and acquiring the research skills needed to lend depth to their thinking. The course will enhance students' ability to think clearly about contentious technology choices, formulate smart positions, and support their views with winning arguments.

05-680 Independent Study in HCI - METALS

All Semesters
With the permission of the professor, METALS students may engage in independent project work on any number of innovative research projects sponsored by faculty. Students must complete an Independent Study Proposal, negotiate the number of units to be earned, submit a contract, and present a tangible deliverable. The Program Advisor's signature is required for the METALS Independent Study course.

05-685 Prototyping Algorithmic Experiences

Intermittent: 15 units
This project-based, technical studio course provides an overview and hands-on introduction to iterative prototyping methods in HCI. Students learn methods and strategies to iteratively prototype novel technologies with users. Students will practice strategically evaluating whether a given prototyping approach is a good fit for a given design or research question (e.g., in terms of expected time, effort, and informativeness). Through a series of rapid course projects, students will explore the cutting-edge of HCI methods for prototyping complex interactive experiences with challenging design materials, such as AI and machine learning, social computing, and spatial computing. In addition to HCI undergraduate majors, the course is open to undergraduate and graduate level students with proficiency in programming and prior courses or experience in user-centered research, design, and/or evaluation. Some exceptions to the course prerequisites will be granted with permission of the instructor.
Prerequisites: 15-112 and (15-210 or 15-150 or 15-122 or 15-121) and (05-891 or 05-651 or 05-650 or 05-652 or 05-610 or 05-617 or 05-660 or 05-392 or 05-670)

05-738 Evidence-Based Educational Design

Fall: 12 units
In this course, we will explore the essential principles of educational design, focusing on creating inclusive environments for diverse learners and promoting positive behavior. We will explore effective strategies for measuring learning outcomes, enhancing student engagement, and assessing educational effectiveness. Students will prepare for careers as instructional designers, learning engineers, educators, and researchers as we cover the range of topics in this class. The coursework includes a thorough examination of current research in learning sciences through various papers and textbooks. Additionally, students will apply these theoretical principles practically by completing two hands-on projects, seeing the direct application of the concepts to real-world use cases. Class time will be spent discussing the weekly readings, highlighting relevant case studies, and engaging in group activities that foster collaboration and practical application of the material covered. This course will prepare students for real-world challenges in educational design and help integrate learning science knowledge through practical experience, enabling them to create effective educational designs and strategies.

05-823 E-Learning Design Principles and Methods

Fall: 12 units
Good design is a continuous improvement process that combines scientific principles and data-driven methods to achieve desired outcomes. E-learning design is no exception. In this course, you will learn how to design innovative e-learning, that is, online interactions and technology that make learning more effective and efficient. You will practice instructional design using learning science theories and principles and learning engineering using data-driven methods to discover insights about how learners think. Instructional designers explain and use principles of learning and instruction such as proven ways to support learning-by-doing, like deliberate practice and self-explanation, and proven ways to support multimedia learning from text, visuals, and audio. They employ "backward design": designing and aligning learning goals, the assessments that measure them, and the instruction that achieves them. But today's learning engineers do not simply design in sequence and #8212; goals then assessments then instruction and #8212; but are agile and iterative. They collect qualitative data, for example, by having an expert "think aloud" while performing one of their assessments and use the results to add or change goals. They collect and use quantitative data, for example, by mining learning data from online course interactions or by comparing alternative designs in an A/B experiment. By using data, learning engineers create innovative and effective designs unlike the results of others who rely on science and intuition alone. You will do so too in an end-to-end e-learning design project, where you develop an e-learning module of your choice, continuously improve it, and test it in an A/B experiment.

Course Website: https://www.hcii.cmu.edu/course/e-learning-design-principles (https://www.hcii.cmu.edu/course/e-learning-design-principles/)

05-839 Interactive Data Science

Spring: 12 units
This course covers techniques and technologies for creating data driven interfaces. You will learn about the entire data pipeline from sensing to cleaning data to different forms of analysis and computation.

Course Website: https://hcii.cmu.edu/academics/courses (https://hcii.cmu.edu/academics/courses/)

05-840 Tools for Online Learning

Fall: 12 units
In this course, we will explore issues that pertain to interaction and interface design. The class will focus on elements of the larger interaction design process including basic design principles, information architecture and navigation, planning and brainstorming methods, and techniques for developing rapid sketches and prototypes. Course Requirements: This class will not focus on learning specific software tools. Students are expected to have prior experience using a variety of design and programming tools. Please speak with the instructor if you have questions regarding these prerequisites. This course was design for students in the METALS program.

SCS Additional Minors

This page lists Additional Majors and Minors apart from those in Artificial Intelligence (p. 674), Computational Biology (p. 679), Computer Science (p. 683) , Human-Computer Interaction (p. 688) and Robotics. Select from the tabs below to view more information about each program.

Students should consult with their own academic advisor as well as the advisor for the given minor for specific double-counting rules, especially for students who are pursuing an SCS minor with a major or other minors closely related to computing. Additional help can be provided by the Associate Dean in the Computer Science Undergraduate Program office (Gates-Hillman Center, 4th Floor).

A note on SCS Concentrations: Computer Science majors are required to pursue a minor outside of SCS or a concentration within SCS. Additional majors in SCS are still allowed for Computer Science majors. Artificial Intelligence, Computational Biology, Human-Computer Interaction and Robotics majors can complete an SCS concentration if they wish, but it is not required for these degrees. Minors in SCS will not be allowed for SCS students where there is an aligned concentration. For example, an SCS student cannot minor in Machine Learning since there is a Machine Learning concentration. Consult the SCS Concentrations section for details on available SCS concentrations.

IDeATe Minors

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The Integrative Design, Arts and Technology (IDeATe) network offers students the opportunity to become immersed in a collaborative community of faculty and peers who share expertise, experience, and passions at the intersection of arts and technology. Students engage in active "learning by doing" in state-of-the-art maker spaces. The program addresses current and emerging real-world challenges that require disciplinary expertise coupled with multidisciplinary perspectives and collaborative integrative approaches.

The IDeATe undergraduate curriculum consists of ten areas, all of which can be taken as minors. The themes of these areas integrate knowledge in technology and the arts. Five of these minors are based in the School of Computer Science:

Animation & Special Effects Minor

Animation & Special Effects comprise a rich field of inquiry at the intersection of art, science, and technology. Students in the IDeATe *Animation & Special Effects* minor will gain experience and competency across a wide range of techniques, while learning about the diverse histories, theories, and practices of animation from renowned faculty experts and visiting artists. Coursework cultivates development of unique aesthetics and individual voice through opportunities for group critique, iteration, public screening and exhibition. Through the minor, students will: have opportunities to collaborate and connect with peers in other fields of research; develop relevant practical skills and abilities that can be applied across a variety of independent studio and industry contexts; deepen cultural sensitivities while expanding their own creative practices; and develop a compelling animation portfolio. In particular, students will gain skills and competencies in the following areas:

- Storytelling through animation
- Digital 2D and 3D animation techniques
- Expanded and experimental animation methods
- Real-time animation systems
- Motion-capture technologies
- Visual effects and procedural animation
- Rendering and compositing

Curriculum

One Computing Course - Minimum of 9 Units

		Units
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
60-212	Intermediate Studio: Creative Coding	12

One IDeATe Portal Course - Minimum of 9 Units

		Units
60-125	IDeATe: Introduction to 3D Animation Pipeline Recommended portal course for this area	12
16-223	IDeATe Portal: Creative Kinetic Systems	10
18-090	Twisted Signals: Multimedia Processing for the Arts	10
53-322	IDeATe: Little Games/Big Stories: Indie Roleplaying Game Studio	9
60-223	IDeATe Portal: Introduction to Physical Computing	10
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis	10
82-250	Digital Realities: Introducing Immersive Technologies for Arts and Culture	9
99-361	IDeATe Portal	9

IDeATe Animation & Special Effects Courses - Minimum of 27 Units

		Units
15-463	Computational Photography	12
15-465/60-414	Animation Art and Technology	12
53-320	IDeATe Special Topics in Animation: Character Modeling	6
53-321	IDeATe Special Topics in Animation: Bipedal Rigging for Animation Production	6
53-323	IDEATE Storytelling Through Effects Animation	6
60-220	IDeATe: Technical Character Animation	10
60-333	IDeATe: Animation Rigging	10
60-335	IDeATe Special Topics in Animation: Story Development	6
60-398	Critical Studies: Social History of Animation	9
60-413	Advanced ETB: Real-Time Animation	10
60-415	Advanced ETB: Animation Studio	10
60-417	Advanced ETB: Video Art	10

Additional course options as available. Please refer to the IDeATe website for courses for the current and upcoming semester.

Double-Counting

Students may double-count up to two of their *Animation & Special Effects* minor courses toward other requirements.

Intelligent Environments Minor

Students in the *Intelligent Environments* minor are concerned with the design and realization of interactive 3D spaces, both physical and virtual. Students in this minor can explore how information and energy flow between physical, electronic, and computational spaces. By moving through space and time, we make sense of the world using our bodies. Just as we shape the environments around us, they in turn shape our experiences and senses, making us mindful of the need to develop responsible, equitable and inclusive environments. As a student in Intelligent Environments, through experimentation, hands-on learning, reflection, and documentation, you will learn:

- Analytical skills for the visualization and realization interactive spaces
- Principles of multimodal and embodied interactions

- 3-dimensional computer-aided design (CAD) for visualization, simulation, and fabrication
- The cultural context, and social and environmental implications of constructed environments

Students in this minor work in tandem with the Physical Computing and Media Design areas, which provide knowledge in key component elements of integrative intelligent environments. Accordingly, students can customize their studies by combining courses across these three concentrations with the help of their advisors.

Curriculum

One Computing Course - Minimum of 9 Units

		Units
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
60-212	Intermediate Studio: Creative Coding	12

One IDeATe Portal Course - Minimum of 9 Units

		Units
16-223	IDeATe Portal: Creative Kinetic Systems Recommended Portal Course for this area	10
60-223	IDeATe Portal: Introduction to Physical Computing Recommended Portal Course for this area	10
18-090	Twisted Signals: Multimedia Processing for the Arts	10
53-322	IDeATe: Little Games/Big Stories: Indie Roleplaying Game Studio	9
60-125	IDeATe: Introduction to 3D Animation Pipeline	12
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis	10
82-250	Digital Realities: Introducing Immersive Technologies for Arts and Culture	9
99-361	IDeATe Portal	9

IDeATe Intelligent Environments Courses - Minimum of 27 Units

		Units
05-333	Gadgets, Sensors and Activity Recognition in HCI	12
16/54-375	IDeATe: Robotics for Creative Practice	10
16-376	IDeATe: Kinetic Fabrics	10
16-467	Introduction to Human Robot Interaction	12
18/05-540	Rapid Prototyping of Computer Systems	12
48-528	IDeATe: Responsive Mobile Environments	9
51-361	HyperSENSE: Augmenting Human Experience in Environments	9
53-558	Reality Computing Studio	12
99-362	IDeATe: Intelligent Learning Spaces	9

Additional course options as available. Please refer to the IDeATe website for courses for the current and upcoming semester.

Double-Counting

Students may double-count up to two of their *Intelligent Environments* minor courses toward other majors and minors.

Design for Learning Minor

Students in the *Design for Learning* minor, offered by the Human-Computer Interaction Institute (http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/addlmajorsminors/hcii.cmu.edu) (HCII), combine skills to imagine, design, iterate, and evaluate effective new media systems for learning—from creating games for learning to integrating adaptive ed-tech and augmented reality experiences into diverse learning settings. In team-based collaborations, students focus on the critical design of learning platforms, products, and systems that leverage emerging technologies, learning science research, inclusive design, and data analytics to create engaging educational experiences with measurable real-world impact.

Through coursework in the minor, you will gain skills and competencies in:

- Learning design research and evaluation methods
- Concept modeling and prototyping techniques
- Learner-centered, inclusive and backward design frameworks
- Applied learning research and theory in team-based projects
- Communicating design choices and concepts to diverse stakeholders

Students in *Design for Learning* courses can bring media-making and prototyping competencies gained in other IDeATe areas (e.g. Game Design, Media Design, Physical Computing, Immersive Technologies in Arts & Humanities) to craft innovative learning experiences.

Curriculum

One Computing Course - Minimum of 9 Units

		Units
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
60-212	Intermediate Studio: Creative Coding	12

One IDeATe Portal Course - Minimum of 9 Units

		Units
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis Recommended Portal Course for this area	10
99-361	IDeATe Portal Recommended Portal Course for this area	9
16-223	IDeATe Portal: Creative Kinetic Systems	10
18-090	Twisted Signals: Multimedia Processing for the Arts	10
53-322	IDeATe: Little Games/Big Stories: Indie Roleplaying Game Studio	9
60-125	IDeATe: Introduction to 3D Animation Pipeline	12
60-223	IDeATe Portal: Introduction to Physical Computing	10
82-250	Digital Realities: Introducing Immersive Technologies for Arts and Culture	9

IDeATe Design for Learning Courses - Minimum of 27 Units

05-291	Learning Media Design	12
05-292	IDeATe: Learning in Museums	12
05-321	Transformational Game Design Studio	12
05-418	Design Educational Games	12
05-432	Personalized Online Learning	12
05-738	Evidence-Based Educational Design	12
05-823	E-Learning Design Principles and Methods	12
51-486	Designing Experiences for Learning	9
79-343	Education, Democracy, and Civil Rights	9
82-288	Everyday Learning: Designing Learning Exp in Times of Unrest & Uncertainty	Var.
90-463	Policy and Leadership in Public Education	6
99-362	IDeATe: Intelligent Learning Spaces	9

Additional course options as available. Please refer to the IDeATe website for courses for the current and upcoming semester.

Double-Counting

Students may double-count up to two of their *Design for Learning* minor courses toward requirements for other majors and minors.

Physical Computing Minor

Physical computing is driven by a creative combination of arts and engineering disciplines. Our students' projects interact with their surroundings, remember information, make decisions, and generate tangible outputs like movement, sound, or light. Physical computing projects range from the tiny and plain (a blinking light on a breadboard) to the extravagant (a simulation of an alien landscape), and everything in between. They may be functional, like an assistive device for a person with disability, playful, like an interactive marble run, or exploratory, like a prototype for a future human-computer interface in a world of sentient machines.

Students gain a broad range of skills in our courses because physical computing as a field is fundamentally interdisciplinary: our projects combine software, electronics, and physical fabrication. Students in the *Physical Computing* minor learn how to:

- Write low-level software to computationally define a project's behavior, usually using C or Python
- Fabricate projects using techniques borrowed from various crafts and disciplines, such as making simple assemblies with paper and tape; woodworking for larger or more robust projects; textile/fabric integrations; and creating powered mechanical linkages using motors/gears/belts/bearings/etc.
- Design, test, assemble, and debug electronic circuits to bring a project to life
- Use 3-dimensional computer-aided design (CAD) for visualization, simulation, and fabrication of all of the above
- Combine digital fabrication techniques (3D printing, laser cutting, etc.) with hand craft to iterate towards creating a final, polished product

Curriculum

One Computing Course - Minimum of 9 Units

		Units
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
60-212	Intermediate Studio: Creative Coding	12

One IDeATe Portal Course - Minimum of 9 Units

		Units
16-223	IDeATe Portal: Creative Kinetic Systems Recommended Portal Course for this area	10
60-223	IDeATe Portal: Introduction to Physical Computing Recommended Portal Course for this area	10
18-090	Twisted Signals: Multimedia Processing for the Arts	10
53-322	IDeATe: Little Games/Big Stories: Indie Roleplaying Game Studio	9
60-125	IDeATe: Introduction to 3D Animation Pipeline	12
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis	10
82-250	Digital Realities: Introducing Immersive Technologies for Arts and Culture	9
99-361	IDeATe Portal	9

IDeATe Physical Computing Courses - Minimum of 27 Units

		Units
05-333	Gadgets, Sensors and Activity Recognition in HCI	12
05/18-540	Rapid Prototyping of Computer Systems	12
15-294	Special Topic: Rapid Prototyping Technologies	5
15-394	Intermediate Rapid Prototyping	5
16/54-375	IDeATe: Robotics for Creative Practice	10
16-376	IDeATe: Kinetic Fabrics	10
16-480	IDeATe: Creative Soft Robotics	10
18/05-540	Rapid Prototyping of Computer Systems	12
18-578	Mechatronic Design	12
24-672	Special Topics in DIY Design and Fabrication	12
39-245	Rapid Prototype Design	9
48-528	IDeATe: Responsive Mobile Environments	9
62-362	IDeATe: Electronic Logics && Creative Practice	12
62-478	IDeATe: digiTOOL	9

Additional course options as available. Please refer to the IDeATe website for courses for the current and upcoming semester.

Double-Counting

Students may double-count up to two of their *Physical Computing* minor courses toward requirements for other majors and minors.

Soft Technologies Minor

Soft technologies is an emerging field of robotics, the arts, craft, and engineering with far-reaching commercial, research, and social implications. Individual disciplines address components of this burgeoning field, but the IDeATe *Soft Technologies* minor helps students integrate the pieces to be able to make significant contributions to this developing sphere. Through the courses in the minor, students weave together a rich set of established and experimental techniques in traditional soft materials (such as fibers and textiles) and new soft materials (such as current hybrid and dynamic materials) to design and create a variety of forms with applications ranging from novel to practical. Students explore the unique qualities that soft material technologies afford in design and interaction in relationship to environments and the human body— responsiveness, adaptivity, flexibility, sensitivity, morphing, and biomimicry. Students will engage in project-based inquiry, using research, experimentation, making, and reflection to inform their creativity and to develop critical perspectives. Students will be able to envision their own projects and develop sensitivities to the breadth and limitations of soft technologies.

Through coursework in the minor, you will gain skills and competencies in:

- Manipulating traditional soft materials (such as fibers and textiles) and new soft materials (such as current hybrid and dynamic materials).
- Constructing 3-dimensional forms from 2-dimensional planes.
- Articulating material and conceptual choices in discussions and critiques.
- Analyzing the relationships between materials, form, use, and content integral to making.
- Researching and engaging with contemporary and/or historical precedents in the field

Curriculum

One Computing Course - Minimum of 9 Units

		Units
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
60-212	Intermediate Studio: Creative Coding	12

One IDeATe Portal Course - Minimum of 9 Units

		Units
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis Recommended Portal Course for this area	10
99-361	IDeATe Portal Recommended Portal Course for this area	9
16-223	IDeATe Portal: Creative Kinetic Systems	10
18-090	Twisted Signals: Multimedia Processing for the Arts	10
53-322	IDeATe: Little Games/Big Stories: Indie Roleplaying Game Studio	9
60-125	IDeATe: Introduction to 3D Animation Pipeline	12
60-223	IDeATe Portal: Introduction to Physical Computing	10
82-250	Digital Realities: Introducing Immersive Technologies for Arts and Culture	9

IDeATe Soft Technologies Courses - Minimum of 27 Units

		Units
09-227	The Culture of Color: Dyes, Chemistry, and Sustainability	9
15-367	Algorithmic Textiles Design	12
16-224	IDeATe: Re-Crafting Computational Thinking with Soft Technologies	6
16-376	IDeATe: Kinetic Fabrics	10
27-505	Exploration of Everyday Materials	9
54-346	Introduction to Costume Construction	6
54-486	Understanding Textiles	3

Additional course options as available. Please refer to the IDeATe website for courses for the current and upcoming semester.

Double-Counting

Students may double-count up to two of their *Soft Technologies* minor courses toward requirements for other majors and minors.

Information Security, Privacy, and Policy Minor

Lujo Bauer, Director

There is a growing demand for security and privacy experts, and increasing interest among CMU undergraduates in taking security and privacy courses. Security and privacy expertise is an asset in a variety of careers outside, not just in computer science, but also in areas that include business, management, and law. In addition, the policy side of security and privacy is becoming increasingly important and employers are interested in hiring people with an understanding of relevant policy issues, especially in the privacy and security area.

This minor is for undergraduate students across the university who are interested in policy issues related to security and privacy, including those who are planning careers in security/privacy as well as those who plan to focus their careers in other areas. The curriculum has been designed to accommodate students from any major as long as they have taken at least one introductory-level college programming course (such as 15-110 or 15-112).

After completing this minor, students will have a good understanding of how to identify potential security and privacy risks and relevant legal and policy issues; a working understanding of security topics such as cryptography, authentication, and Internet security protocols; as well as broad knowledge of several security- and privacy-related areas as they pertain to the design, development, deployment and management of technologies in a variety of practical contexts (e.g., Web, mobile, Internet of Things, social media, crypto currencies).

Admission

Students are not required to apply to enroll in this minor to start the required courses. However, students should declare their intent to complete the minor and submit a planned course of study to the minor director, and are encouraged to consult with the minor director on their elective course selection. In addition, students doing the independent study option must get approval from the minor director prior to enrolling in their independent study course. Finally, students must contact the minor director to certify their completion of the minor.

Curriculum

Students are required to take five courses to complete this minor with a minimum of 48 units.

INTRODUCTORY SECURITY COURSE

17-331	Information Security, Privacy, and Policy	12

Students who have taken 15-213 Introduction to Computer Systems may substitute 15-330 Introduction to Computer Security/18-330 Introduction to Computer Security

PRIVACY AND POLICY COURSE

17-333	Privacy Policy, Law, and Technology	9

Students may substitute 12-unit version of this course: 17-733, 19-608, or 95-818.

PRIVACY ELECTIVE

Complete a minimum of 9 units:		Units
17-334	Usable Privacy and Security (or 19-534 or 05-436)	9
17-702	Current Topics in Privacy Seminar (3-unit Mini)	3
17-731	Foundations of Privacy	12
17-735	Engineering Privacy in Software	12
17-880	Algorithms for Private Data Analysis	12
94-806	Privacy in the Digital Age	6

Crosslisted courses are also allowed.

TECHNOLOGY AND POLICY ELECTIVE

Complete a minimum of 9 units:		Units
17-200	Ethics and Policy Issues in Computing	9
19-211	Ethics and Policy Issues in Computing	9
17-562	Law of Computer Technology	9
19-101	Introduction to Engineering and Public Policy	12
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-403	Policies of Wireless Systems	12
19-639	Policies of the Internet	12
84-387	Remote Systems and the Cyber Domain in Conflict	9

Crosslisted courses are also allowed.

ADDITIONAL APPROVED ELECTIVE

Students must complete an additional elective of 9 units or more. Students may choose an additional privacy elective or technology policy elective from the list above, or the one of the following security electives:

15-316	Software Foundations of Security and Privacy	9
15-356	Introduction to Cryptography	12
17-303	Cryptocurrencies, Blockchains and Applications	Var.
17-334	Usable Privacy and Security	9
18-335	Secure Software Systems	12
18-733	Applied Cryptography	
18-435	Foundations of Blockchains	12
18-334	Network Security	12

Students who have the necessary prerequisites may choose any approved elective from the SCS or ECE security and privacy undergraduate concentration. Check with the minor program director to determine which category of elective each course will fulfill.

Students should be careful to choose electives for which they have appropriate prerequisites. New elective options are expected as more courses are offered. Students may petition to count a course not on this list as an elective. Students should request permission *before* taking a course that is not on this list. Students may not count multiple electives that overlap substantially.

Optional Project: Subject to approval by the minor director, students may optionally count towards one of the elective requirements 9 units of an independent study or research project course in the security or privacy area, under the supervision of a faculty member in any department. In order to receive credit towards the minor, students must submit a brief project proposal to their project advisor and to the minor director and have it approved prior to conducting the project. Depending on the topic of the project, the minor director may approve credits counting towards privacy electives, technology policy electives, security electives, or some combination of these. Students may work individually, with other undergraduates, or as part of project teams with graduate students or research staff. Students involved in a group project must identify specific project components for which they are responsible. In addition, they must submit a final project report to their project advisor and the minor director that includes a literature review and describes the work they completed. Students working on a group project must each submit their own final report, which should also situate their contribution in the context of the larger project. Note, students are expected to work approximately 1 hour per week for each unit of project in which they are enrolled (e.g. 9 units = 9 hours/week of project work).

Double Counting: At most 2 of the courses used to fulfill the minor requirements may be counted towards any other undergraduate major or minor program. This rule does not apply to courses counted for general education requirements.

Language Technologies Minor

Carolyn P. Rose, *Chair*
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www.lti.cs.cmu.edu/learn (http://www.lti.cs.cmu.edu/learn/)

Human language technologies have become an increasingly central component of computer science. Information retrieval, machine translation and speech technology are used daily by the general public, while text mining, natural language processing and language-based tutoring are common within more specialized professional or educational environments. The Language Technologies Institute prepares students for this world by offering a minor that gives you the opportunity to not only learn about language technologies, but to also apply that knowledge through a directed project.

Prerequisites

Prerequisites		Units
15-122	Principles of Imperative Computation	12
15-150	Principles of Functional Programming	12

Recommended		
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
15-259	Probability and Computing	12
or 21-325	Probability	
or 36-218	Probability Theory for Computer Scientists	

Curriculum

Core requirement:		
11-324	Human Language for Artificial Intelligence	12

Electives (choose 3):		
11-344	Machine Learning in Practice	12
11-411	Natural Language Processing	12
11-441	Machine Learning with Graphs	9
11-442	Search Engines	9
11-492	Speech Technology for Conversational AI	12
11-711	Advanced Natural Language Processing	12
11-731	Machine Translation and Sequence-to-Sequence Models	12
11-737	Multilingual Natural Language Processing.	12
11-747	Neural Networks for NLP	12
11-751	Speech Recognition and Understanding	12
11-752	Speech II: Phonetics, Prosody, Perception and Synthesis	12
11-761	Language and Statistics	12
11-776	Multimodal Affective Computing	12
80-180	Nature of Language: An Introduction to Linguistics	9
80-280	Linguistic Analysis	9

Project:	
A semester-long directed research project OR paper to provide hands-on experience and an in-depth study of a topic (in same area as a chosen elective)	12

Double Counting of Courses

Students may double count 11-324 Human Language for Artificial Intelligence and 80-180 Nature of Language: An Introduction to Linguistics toward any other major or minor.

Machine Learning Minor

Dr. Matt Gormley, *Program Director*
Laura Winter, *Program Coordinator*
ml-minor@cs.cmu.edu
www.ml.cmu.edu/academics/minor-in-machine-learning.html (http://www.ml.cmu.edu/academics/minor-in-machine-learning.html)

Machine learning and statistical methods are increasingly used in many application areas including natural language processing, speech, vision, robotics, and computational biology. The Minor in Machine Learning allows undergraduates to learn about the core principles of this field.

Prerequisites

The 3 prerequisite courses must be taken before a student applies to the Machine Learning Minor.

Prerequisites		Units
15-122	Principles of Imperative Computation	12
15-151	Mathematical Foundations for Computer Science	12
or 21-127	Concepts of Mathematics	
or 21-128	Mathematical Concepts and Proofs	
36-235	Probability and Statistical Inference I	9
or 36-218	Probability Theory for Computer Scientists	
or 36-219	Probability Theory and Random Processes	
or 36-225	Introduction to Probability Theory	
or 15-259	Probability and Computing	
or 21-325	Probability	

Core Courses

The Machine Learning Minor has 2 core courses that provide a foundation in the field.

Core Courses		
10-301	Introduction to Machine Learning	12
or 10-315	Introduction to Machine Learning (SCS Majors)	
10-403	Deep Reinforcement Learning & Control	12
or 10-405	Machine Learning with Large Datasets (Undergraduate)	
or 10-417	Intermediate Deep Learning	
or 10-418	Machine Learning for Structured Data	

Electives

The Machine Learning Minor requires at least 3 electives of at least 9 units each in Machine Learning. Students may select one of the following options to satisfy the electives requirement:

- 3 Principal courses
- 2 Principal courses + 1 Interdisciplinary course
- 2 Principal courses + 1 semester of CS Senior Honors Thesis or Senior Research
- 1 Principal course + 2 semesters of CS Senior Honors Thesis or Senior Research

Students should note that some of these elective courses (those at the 600-level and higher) are primarily aimed at graduate students, and so should make sure that they are adequately prepared for them before enrolling.

Graduate-level cross-listings of these courses can also be used for the ML Minor, if the student is adequately prepared for the more advanced version and the home department approves the student's registration.

Principal Electives

10-403	Deep Reinforcement Learning & Control	12
or 10-703	Deep Reinforcement Learning & Control	
10-405	Machine Learning with Large Datasets (Undergraduate)	12
or 10-605	Machine Learning with Large Datasets	
or 10-745	Scalability in Machine Learning	
10-414	Deep Learning Systems: Algorithms and Implementation	12
10-417	Intermediate Deep Learning	12
or 11-485	Introduction to Deep Learning	
or 10-707	Advanced Deep Learning	
10-418	Machine Learning for Structured Data	12
or 10-708	Probabilistic Graphical Models	
10-425	Introduction to Convex Optimization	12
or 10-725	Convex Optimization	
10-613	Machine Learning Ethics and Society	12
10-777	Historical Advances in Machine Learning	12
36-401	Modern Regression	9
Other courses as approved		

Note: Courses must come from separate lines. For example, if 10-417 Intermediate Deep Learning is used for the ML Minor, 11-485 Introduction to Deep Learning cannot also be used for the ML Minor.

Interdisciplinary Electives

02-510	Computational Genomics	12
03-511	Computational Molecular Biology and Genomics	9
10-335	Art and Machine Learning	12
10-737	Creative AI	Var.
11-411	Natural Language Processing	12
11-441	Machine Learning with Graphs	9
11-661	Language and Statistics	12
11-731	Machine Translation and Sequence-to-Sequence Models	12
11-751	Speech Recognition and Understanding	12
11-755	Machine Learning for Signal Processing	12
11-777	Multimodal Machine Learning	12
15-281	Artificial Intelligence: Representation and Problem Solving	12

15-386	Neural Computation	9
15-388	Practical Data Science	9
15-482	Autonomous Agents	12
16-311	Introduction to Robotics	12
16-385	Computer Vision	12
16-720	Computer Vision	12
16-745	Optimal Control and Reinforcement Learning	12
16-824	Visual Learning and Recognition	12
16-831	Introduction to Robot Learning	12
17-537	Artificial Intelligence Methods for Social Good	9
36-402	Advanced Methods for Data Analysis	9
36-462	Special Topics: Statistical Machine Learning	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-700	Probability and Mathematical Statistics	12
Other courses as approved		

SCS Senior Honors Thesis

The SCS Senior Honors Thesis consists of 36 units of academic credit for this work. Up to 24 units (12 units each semester) may be counted towards the ML Minor. Students must consult with the Computer Science Department for information about the SCS Senior Honors Thesis. Once both student and advisor agree upon a project, the student should submit a one-page research proposal to the Machine Learning Concentration Director to confirm that the project will count for the Machine Learning Concentration.

07-599	SCS Honors Undergraduate Research Thesis	Var.

Senior Research

Senior research consists of 2 semesters of 10-500 Senior Research Project, totaling 24 units and counting as 2 electives.

The research must be a year-long senior project, supervised or co-supervised by a Machine Learning Core or Affiliated Faculty member. It is almost always conducted as two semester-long projects, and must be done in senior year. Some samples of available Machine Learning Senior Projects are available on the Machine Learning Department webpage.

Interested students should contact the faculty they wish to advise them to discuss the research project, before the semester in which research will take place. Once both student and advisor agree upon a project, the student should submit a one-page research proposal to the Machine Learning Minor Director to confirm that the project will count for the Machine Learning Minor.

The student should expect to meet with the Minor Director during both Senior Fall and Spring to discuss the project, and will present the work and submit a year-end write-up to the Minor Director at the end of Senior year.

10-500	Senior Research Project	24

Double Counting

No course in the Machine Learning Minor may be counted towards another SCS minor. Additionally, at least 3 courses (each being at least 9 units) must be used for only the Machine Learning Minor, not for any other major, minor, or concentration. (These double counting restrictions apply specifically to the Core Courses and the Electives. Prerequisites may be counted towards other majors, minors, and concentrations and do not count towards the 3 courses that must be used for only the Machine Learning Minor.)

GRADES

All courses for the Machine Learning Minor, including prerequisites, must be passed with a C or better.

ADMISSION

The Machine Learning Minor is open to undergraduate students in any major at Carnegie Mellon outside the School of Computer Science. (SCS students should instead consider the Machine Learning Concentration.) Students should apply for admission at least one semester before their expected graduation date, but are encouraged to apply as soon as they have taken the prerequisite classes for the minor. The application can be found on the Machine Learning Minor website.

Neural Computation Minor

Dr. Tai Sing Lee, *Director*
Melissa Stupka, *Administrative Coordinator*
https://www.cmu.edu/ni/academics/minor-in-neural-computation.html

Neural computation is a scientific enterprise to understand the neural basis of intelligent behaviors from a computational perspective. Study of neural computation includes, among others, decoding neural activities using statistical and machine learning techniques, and developing computational theories and neural models of perception, cognition, motor control, decision-making and learning. The neural computation minor allows students to learn about the brain from multiple perspectives, and to acquire the necessary background for graduate study in neural computation. Students enrolled in the minor will be exposed to, and hopefully participate in, the research effort in neural computation and computational neuroscience at Carnegie Mellon University.

The minor in Neural Computation is an intercollege minor jointly sponsored by the School of Computer Science, the Mellon College of Science, and the Dietrich College of Humanities and Social Sciences, and is coordinated by the Neuroscience Institute (https://www.cmu.edu/ni/) and the Center for the Neural Basis of Cognition (CNBC) (http://www.cnbc.cmu.edu/).

The Neural computation minor is open to students in any major of any college at Carnegie Mellon. It seeks to attract undergraduate students from computer science, psychology, engineering, biology, statistics, physics, and mathematics from SCS, CIT, H&SS and MCS.

The Neural Computation minor is open to students in any major of any college at Carnegie Mellon. It seeks to attract undergraduate students from computer science, psychology, engineering, biology, statistics, physics, and mathematics from SCS, CIT, Dietrich College and MCS. The primary objective of the minor is to encourage students in biology and psychology to take computer science, engineering and mathematics courses, to encourage students in computer science, engineering, statistics and physics to take courses in neuroscience and psychology, and to bring students from different disciplines together to form a community. The curriculum and course requirements are designed to maximize the participation of students from diverse academic disciplines. The program seeks to produce students with both basic computational skills and knowledge in cognitive science and neuroscience that are central to computational neuroscience.

APPLICATION

Students must apply for admission no later than November 30 of their senior years; an admission decision will usually be made within one month. Students are encouraged to apply as early as possible in their undergraduate careers so that the director of the Neural Computation minor can provide advice on their curriculum, but should contact the program director any time even after the deadline.

To apply, send email to the director of the Neural Computation minor Dr. Tai Sing Lee (tai@cnbc.cmu.edu) and copy Melissa Stupka (mstupka@andrew.cmu.edu). Include in your email:

- Full name
- Andrew ID
- Preferred email address (if different)
- Your class and College/School at Carnegie Mellon
- Semester you intend to graduate
- All (currently) declared majors and minors
- Statement of purpose (maximum 1 page) – Describes why you want to take this minor and how it fits into your career goals
- Proposed schedule of required courses for the Minor (this is your plan, NOT a commitment)
- Research projects you might be interested in

Curriculum

The Minor in Neural Computation will require a total of five courses: four courses drawn from the four core areas (A: neural computation, B: neuroscience, C: cognitive psychology, D: intelligent system analysis), one from each area, and one additional depth elective chosen from one of the core areas that is outside the student's major. The depth elective can be replaced by a one-year research project in computational neuroscience. No more than two courses can be double counted toward the student's major or other minors. However, courses taken for general education requirements of the student's degree are not considered to be double counted. A course taken to satisfy one core area cannot be used to satisfy the course requirement for another core area. The following listing presents a set of current possible courses in each area. Other computational neuroscience courses are being developed at Carnegie Mellon and University of Pittsburgh that will also satisfy core area A requirement and the requirements will be updated as they come on-line. Substitution is possible but requires approval.

A. Neural Computation

		Units
15-386	Neural Computation	9
15-387	Computational Perception	9

15-883	Computational Models of Neural Systems	12
85-419	Introduction to Parallel Distributed Processing	9
86-375	Computational Perception	9
Pitt-Mathematics-1800 Introduction to Mathematical Neuroscience		9

B. Neuroscience

03-362	Cellular Neuroscience	9
03-363	Systems Neuroscience	9
03-365	Neural Correlates of Learning and Memory	9
42-630	Introduction to Neural Engineering (crosslisted with 18-690)	12
85-765	Cognitive Neuroscience	9
Pitt-Neuroscience 1000 Introduction to Neuroscience		9

C. Cognitive Psychology

85-211	Cognitive Psychology	9
85-213	Human Information Processing and Artificial Intelligence	9
85-412	Cognitive Modeling	9
85-419	Introduction to Parallel Distributed Processing	9
85-426	Learning in Humans and Machines	9
85-765	Cognitive Neuroscience	9

D. Intelligent System Analysis

10-301	Introduction to Machine Learning	12
or 10-315	Introduction to Machine Learning (SCS Majors)	
15-281	Artificial Intelligence: Representation and Problem Solving	12
15-386	Neural Computation	9
15-387	Computational Perception	9
15-494	Cognitive Robotics: The Future of Robot Toys	12
16-299	Introduction to Feedback Control Systems	12
16-311	Introduction to Robotics	12
16-385	Computer Vision	12
18-290	Signals and Systems	12
24-352	Dynamic Systems and Controls	12
36-225	Introduction to Probability Theory	9
36-401	Modern Regression	9
36-410	Introduction to Probability Modeling	9
42-631	Neural Data Analysis	12
42-632	Neural Signal Processing	12
86-375	Computational Perception	9
86-631	Neural Data Analysis	12

Prerequisites

The required courses in the above four core areas require a number of basic prerequisites: basic programming skills at the level of 15-110 Principles of Computing and basic mathematical skills at the level of 21-122 Integration and Approximation or their equivalents. Some courses in Area D require additional prerequisites. Area B Biology courses require, at minimum, 03-121 Modern Biology. Students might skip the prerequisites if they have the permission of the instructor to take the required courses. Prerequisite courses are typically taken to satisfy the students' major or other requirements. In the event that these basic skill courses are not part of the prerequisite or required courses of a student's major, one of them can potentially count toward the five required courses (e.g. the depth elective), conditional on approval by the director of the minor program.

Research Requirements (Optional)

The minor itself does not require a research project. The student however may replace the depth elective with a year-long research project. In special circumstances, a research project can also be used to replace one of the five courses, as long as (1) the project is not required by the student's major or other minor, (2) the student has taken a course in each of the four core areas (not necessarily for the purpose of satisfying this minor's requirements), and (3) has taken at least three courses in this curriculum not counted toward the student's major or other minors. Students interested in participating in the research project should contact any faculty engaged in computational neuroscience or neural computation research at Carnegie Mellon or in the University of Pittsburgh. A useful webpage that provides listing of faculty in neural computation is https://www.cmu.edu/ni/academics/pnc/pnc-training-faculty.html. The director of the minor program will be happy to discuss with students about their research interest and direct them to the appropriate faculty.

Fellowship Opportunities

The Program in Neural Computation (PNC) administered by the Center for the Neural Basis of Cognition currently provides 3-4 competitive full-year fellowships ($11,000) to Carnegie Mellon undergraduate students to carry out mentored research in neural computation. The fellowship has course requirements similar to the requirements of the minor. Students do not apply to the fellowship program directly. They have to be nominated by the faculty members who are willing to mentor them. Therefore, students interested in the full-year fellowship program should contact and discuss research opportunities with any CNBC faculty at Carnegie Mellon or University of Pittsburgh working in the area of neural computation or computational neuroscience and ask for their nomination by sending email to Dr. Tai Sing Lee, who also administers the undergraduate fellowship program at Carnegie Mellon. See www.cnbc.cmu.edu/training/undergraduate/undergraduate-research-fellowships-in-computational-neuroscience/ (http://www.cnbc.cmu.edu/training/undergraduate/undergraduate-research-fellowships-in-computational-neuroscience/) for details.

The Program in Neural Computation also offers a summer training program for undergraduate students from any U.S. undergraduate college. The students will engage in a 10-week intense mentored research and attend a series of lectures in neural computation. See www.cnbc.cmu.edu/training/undergraduate/summer-undergraduate-research-program-in-computational-neuroscience/ (http://www.cnbc.cmu.edu/training/undergraduate/summer-undergraduate-research-program-in-computational-neuroscience/) for application information.

Software Engineering Minor

Michael Hilton, *Director*
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http://s3d.cmu.edu/education/undergrad (http://isri.cmu.edu/education/undergrad/)

Effectively building modern software systems at scale requires not just programming skills, but also engineering skills. These skills include the ability to interact effectively with customers to gather the requirements for a system in a precise way; to develop a design that resolves competing quality attributes; to make tradeoffs among schedule, cost, features, and quality to maximize value to stakeholders; to work effectively with other engineers; and to assure the quality of the delivered software system. We hear regularly from industry that these skills are crucial to them, and that they are interested in students with a strong software engineering background.

The software engineering minor is designed to teach the fundamental tools, techniques, and processes of software engineering. Through internships and a mentored project experience, students gain an understanding of the issues of scale and complexity that motivate software engineering tools and techniques. The core curriculum includes material both on engineering the software product and on the process, teamwork, and management skills that are essential to successful engineering. Graduates of the program should have the technical, process, and teamwork skills to be immediately productive in a mature engineering organization.

Admission

The Software Engineering Minor is open to non-SCS undergraduate students in any major in the university. We encourage students to submit applications no later than 3 days before the beginning of Spring and Fall course registration, so that subsequent decisions can help students plan their subsequent course schedule effectively. However, students may petition the Director for admission outside this general schedule.

To apply, send the director an email. Include in your email:

- Full name
- Andrew ID
- Preferred email address (if different)
- Semester you intend to graduate
- QPA
- All (currently) declared majors and minors, or home college if no major declared
- Statement of purpose (maximum 1 page) - Describes why you want to take this minor and how it fits into your career goals
- Proposed schedule of required courses and internship (this is your plan, NOT a commitment)

Prerequisite

17-214	Principles of Software Construction: Objects, Design, and Concurrency	12
or 15-214	Principles of Software Construction: Objects, Design, and Concurrency	

Core Course Requirements

Complete both of the following courses.		
17-313	Foundations of Software Engineering	12
or 15-313	Foundations of Software Engineering	
17-413	Software Engineering Practicum	12
or 15-413	SEE 17-413 Software Engineering Practicum	

Electives

The minor requires three elective courses, one selected from each of the following categories:

1. One domain-independent course focused on technical software engineering material (min. 9 units):

Must complete at least 9 units, may comprise one 9-12 unit course or multiple minis		
15-414	Bug Catching: Automated Program Verification	9
17-355	Program Analysis	12
17-356	Software Engineering for Startups	12
17-480	API Design and Implementation	12
17-653	Managing Software Development (Prerequisite 17-413 or internship)	6
17-614	Formal Methods ** Mini pair with 17-624	6
17-612	Business and Marketing Strategy **Mini: pair with either 17-626 or 17-627	6
17-622	Agile Methods ** Mini pair with another min-course of your choice from this list	6
17-623	Quality Assurance ** Mini pair with 17-443/17-643	6
17-731	Foundations of Privacy	12
17-423	Designing Large-scale Software Systems	12

Crosslisted courses allowed.

Other courses may be allowed, with prior approval from the Director of the Software Engineering Program.

2. One engineering-focused course with a significant software component (min. 9 units):

At least 9 units of the following:		
15-410	Operating System Design and Implementation	15
15-412	Operating System Practicum	9
17-437	Web Application Development	12
15-440	Distributed Systems	12
17-422	Building User-Focused Sensing Systems	12
15-441	Networking and the Internet	12
15-445	Database Systems	12
18-749	Building Reliable Distributed Systems	12
67-443	Mobile Application Design and Development	12

Crosslisted courses allowed

Other courses may be allowed, with prior approval from the Director of the Software Engineering Program.

3. One course that explores computer science problems in society and industry, related to existing and emerging technologies and their associated social, political, legal, business, and organizational contexts (min. 9 units):

At least 9 units of the following:		
15-390	Entrepreneurship for Computer Science	9
17-200	Ethical Dilemmas and Policy Issues in Computing	9
70-311	Organizational Behavior	9
17-331	Information Security and Privacy	12
17-333	Privacy Policy, Law, and Technology	9
17-334	Usable Privacy and Security	9
19-403	Policies of Wireless Systems	12
70-471	Supply Chain Management	9
17-562	Law of Computer Technology	9
17-781	Mobile and IoT Computing Services	12
17-801	Dynamic Network Analysis	12
17-821	Computational Modeling of Complex Socio-Technical Systems	12
88-341	Organizational Communication	9

Crosslisted courses allowed.

Required Internship and Reflection Course

A software engineering internship of a minimum of 8 full-time weeks in an industrial setting is required. The student must be integrated into a team and exposed to industry pressures. The intern may work in development, management, quality assurance, or other relevant positions. The director of the SE minor program has sole discretion in approving an internship experience based on these criteria. Students should confirm that an internship position is appropriate before accepting it, but internships that fulfill the criteria will also be accepted after the fact.

- 17-415 *Software Engineering Reflection (required 6 unit course, number to be determined, to be offered Fall semester):* Each student will conduct an analysis of some personal software engineering experience, typically (but not always) based on the engineering internship above. The student will then write and edit a short paper presenting this analysis. Initial course meetings will cover the reflective, writing, and speaking process. In later meetings, each student will present his or her experience through a 30-45 minute talk, which will be evaluated for communication skills and critical reflective content. This course is limited to enrollment of 16, and students who are admitted to the minor program are given first priority.

Double Counting Rule

At most 2 of the courses used to fulfill the minor requirements may be counted towards any other major or minor program. This rule does not apply to 17-214 (a prerequisite for the minor) or courses counted for general education requirements, nor does it apply to double-counting with the SCS General Education requirements.

Other Departments and Institutes Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

Computational Biology Courses

02-112 Programming for Scientists

Intermittent: 12 units
Provides a practical introduction to programming for students with little or no prior programming experience who are interested in science. Fundamental scientific algorithms will be introduced, and extensive programming assignments will be based on analytical tasks that might be faced by scientists, such as parsing, simulation, and optimization. Principles of good software engineering will also be stressed. The course will introduce students to the Go programming language, an industry-supported, modern programming language, the syntax of which will be covered in depth. Other assignments will be given in other programming languages such as Python and Java to highlight the commonalities and differences between languages. No prior programming experience is assumed, and no biology background is needed. Analytical skills and mathematical maturity are required.

02-180 Great Ideas in Computational Biology I

Spring: 5 units
This course introduces great ideas that have formed the foundation for the recent transformation of life sciences into a fully-fledged computational discipline. Extracting biological understanding from both large and small data sets now requires the use and design of novel algorithms, developed in the field of computational biology. The course is designed as a gateway exposure to computational biology for first-year undergraduates in the School of Computer Science, although it is open to other computationally minded students who are interested in exploring the field. This course is the first in a two-course sequence, showing students fundamental algorithmic techniques that are used in modern biological investigations. This first course focuses on algorithmic techniques for genomics, or the study of DNA, and it addresses questions like and amp;quot;How do we reconstruct the sequence of a genome? and amp;quot;, How do we compare genes and genomes?, and and amp;quot;How can we build evolutionary trees to infer relationships among many species? and amp;quot; Previous exposure to molecular biology is not required.
Prerequisites: (15-112 or 02-201) and (21-128 or 21-127 or 15-151)

02-181 Great Ideas in Computational Biology IIx

Spring: 5 units
This course introduces great ideas that have formed the foundation for the recent transformation of life sciences into a fully-fledged computational discipline. Extracting biological understanding from both large and small data sets now requires the use and design of novel algorithms, developed in the field of computational biology. This course is the second in a two-course sequence, offering a gateway exposure for students showing fundamental algorithmic techniques that are used in modern biological investigations. It is designed for first-year undergraduates in the School of Computer Science, although it is open to other computationally minded students who are interested in exploring the field. Whereas the first course in the sequence focuses on genomics, this second course largely introduces topics outside of DNA, from proteins, to neural networks, to a study of algorithms that nature has evolved to solve problems. Previous exposure to molecular biology is not required. After completion of the course, students will be well equipped to tackle advanced computational challenges in biology.
Prerequisites: (02-201 or 15-112) and (15-151 or 21-127 or 21-128)

02-201 Programming for Scientists

Fall and Spring: 10 units
Provides a practical introduction to programming for students with little or no prior programming experience who are interested in science. Fundamental scientific algorithms will be introduced, and extensive programming assignments will be based on analytical tasks that might be faced by scientists, such as parsing, simulation, and optimization. Principles of good software engineering will also be stressed. The course will introduce students to the Go programming language, an industry-supported, modern programming language, the syntax of which will be covered in depth. Other assignments will be given in other programming languages such as Python and Java to highlight the commonalities and differences between languages. No prior programming experience is assumed, and no biology background is needed. Analytical skills and mathematical maturity are required. Course not open to CS majors.

02-218 Introduction to Computational Medicine

All Semesters: 3 units
This course is an introduction to computational methods relevant to the diagnosis and treatment of human diseases. It is the microcourse version of 02-518, Computational Medicine. The course begins with an introduction to the field of Medicine, and an overview of the primary clinical tasks associated with Computational Medicine (phenotyping; biomarker discovery; predictive modeling). Next, we provide an introduction to several Machine Learning techniques, and how those techniques can be used to perform the clinical tasks. For the remainder of the course, students will be guided through the analysis of a clinical data set to gain experience with these techniques. No prior experience with Medicine, Machine Learning, or computer programming is required. Students will be graded based on quizzes and one homework.

02-223 Personalized Medicine: Understanding Your Own Genome

Fall: 9 units
Do you want to know how to discover the tendencies hidden in your genome? Since the first draft of a human genome sequence became available at the start of this century, the cost of genome sequencing has decreased dramatically. Personal genome sequencing will likely become a routine part of medical exams for patients for prognostic and diagnostic purposes. Personal genome information will also play an increasing role in lifestyle choices, as people take into account their own genetic tendencies. Commercial services such as 23andMe have already taken first steps in this direction. Computational methods for mining large-scale genome data are being developed to unravel the genetic basis of diseases and assist doctors in clinics. This course introduces students to biological, computational, and ethical issues concerning use of personal genome information in health maintenance, medical practice, biomedical research, and policymaking. We focus on practical issues, using individual genome sequences (such as that of Nobel prize winner James Watson) and other population-level genome data. Without requiring any background in biology or CS, we begin with an overview of topics from genetics, molecular biology, stats, and machine learning relevant to the modern personal genome era. We then cover scientific issues such as how to discover your genetic ancestry and how to learn from genomes about migration and evolution of human populations. We discuss medical aspects such as how to predict whether you will develop diseases such as diabetes based on your own genome, how to discover disease-causing genetic mutations, and how genetic information can be used to recommend clinical treatments.

02-250 Introduction to Computational Biology

Spring: 12 units
This class provides a general introduction to computational tools for biology. The course is divided into two halves. The first half covers computational molecular biology and genomics. It examines important sources of biological data, how they are archived and made available to researchers, and what computational tools are available to use them effectively in research. In the process, it covers basic concepts in statistics, mathematics, and computer science needed to effectively use these resources and understand their results. Specific topics covered include sequence data, searching and alignment, structural data, genome sequencing, genome analysis, genetic variation, gene and protein expression, and biological networks and pathways. The second half covers computational cell biology, including biological modeling and image analysis. It includes homework requiring modification of scripts to perform computational analyses. The modeling component includes computer models of population dynamics, biochemical kinetics, cell pathways, and neuron behavior. The imaging component includes the basics of machine vision, morphological image analysis, image classification and image-derived models. The course is taught under two different numbers. The lectures are the same for both but recitations and examinations are separate. 02-250 is intended primarily for computational biology, computer science, statistics or engineering majors at the undergraduate or graduate level who have had prior experience with computer science or programming. 03-250 is intended primarily for biological sciences or biomedical engineering majors who have had limited prior experience with computer science or programming. Students may not take both 02-250 and 03-250 for credit. Prerequisite: (02-201 or 15-110 or 15-112), or permission of the instructors.
Prerequisites: (02-201 or 15-112 or 15-110) and (03-131 or 03-151 or 03-121)

Course Website: http://www.cbd.cmu.edu/education/undergraduate-courses/introduction-to-computational-biology/

02-251 Great Ideas in Computational Biology

Spring: 12 units
This 12-unit course provides an introduction to many of the great ideas that have formed the foundation for the recent transformation of life sciences into a fully-fledged computational discipline. Extracting biological understanding from both large and small data sets now requires the use and design of novel algorithms, developed in the field of computational biology. This gateway course is intended as a first exposure to computational biology for first-year undergraduates in the School of Computer Science, although it is open to other computationally minded 6students who are interested in exploring the field. Students will learn fundamental algorithmic and machine learning techniques that are used in modern biological investigations, including algorithms to process string, graph, and image data. They will use these techniques to answer questions such as "How do we reconstruct the sequence of a genome?", "How do we infer evolutionary relationships among many species?", and "How can we predict each gene's biological role?" on biological data. Previous exposure to molecular biology is not required, as the instructors will provide introductory materials as needed. After completion of the course, students will be well equipped to tackle advanced computational challenges in biology.
Prerequisites: (15-112 or 02-201) and (21-128 or 15-151 or 21-127)

02-261 Quantitative Cell and Molecular Biology Laboratory

Fall and Spring
This is an introductory laboratory-based course designed to teach basic biological laboratory skills used in exploring the quantitative nature of biological systems and the reasoning required for performing research in computational biology. Over the course of the semester, students will design and perform multiple modern experiments and quantitatively analyze the results of these experiments. During this course students will also have an opportunity to use techniques learned during the course to experimentally answer an open question. Designing the experiments will require students to think critically about the biological context of the experiments as well as the necessary controls to ensure interpretable experimental results. During this course students will gain experience in many aspects of scientific research, including: sequencing DNA, designing and performing PCR for a variety of analyses, maintaining cell cultures, taking brightfield and fluorescent microscopy images, developing methods for automated analysis of cell images, communicating results to peers and colleagues. Course Outline: (1) 3-hour lab per week, (1) 1-hour lecture per week.
Prerequisites: 02-201 or 15-112

02-262 Computation and Biology Integrated Research Lab

All Semesters
Modern biological research is heavily interdisciplinary in nature requiring the use of a diverse set of experimental techniques and computational analysis. This course provides students with a modern research experience while training them to communicate and collaborate in an interdisciplinary setting to better prepare them to join the workforce as members of interdisciplinary teams. This will be accomplished by focusing efforts on a real research problem requiring sophisticated experimentation and computation for success. Class time will include both laboratory research time (wet lab and computational) and activities designed to teach and practice communication methods for interdisciplinary teams. Students are expected to have a strong background in biology or computation and an interest in both. Pre-requisites include either (03-117 or 03-124 or 03-343) or (15-112 or equivalent)

02-317 Algorithms in Nature

Intermittent: 9 units
Computer systems and biological processes often rely on networks of interacting entities to reach joint decisions, coordinate and respond to inputs. There are many similarities in the goals and strategies of biological and computational systems which suggest that each can learn from the other. These include the distributed nature of the networks (in biology molecules, cells, or organisms often operate without central control), the ability to successfully handle failures and attacks on a subset of the nodes, modularity and the ability to reuse certain components or sub-networks in multiple applications and the use of stochasticity in biology and randomized algorithms in computer science. In this course we will start by discussing classic biologically motivated algorithms including neural networks (inspired by the brain), genetic algorithms (sequence evolution), non-negative matrix factorization (signal processing in the brain), and search optimization (ant colony formation). We will then continue to discuss more recent bi-directional studies that have relied on biological processes to solve routing and synchronization problems, discover Maximal Independent Sets (MIS), and design robust and fault tolerant networks. In the second part of the class students will read and present new research in this area. Students will also work in groups on a final project in which they develop and test a new biologically inspired algorithm. No prior biological knowledge required.
Prerequisites: 15-210 and 15-251

Course Website: http://www.algorithmsinnature.org

02-319 Genomics and Epigenetics of the Brain

Fall: 9 units
This course will provide an introduction to genomics, epigenetics, and their application to problems in neuroscience. The rapid advances in single cell sequencing and other genomic technologies are revolutionizing how neuroscience research is conducted, providing tools to study how different cell types in the brain produce behavior and contribute to neurological disorders. Analyzing these powerful new datasets requires a foundation in molecular neuroscience as well as key computational biology techniques. In this course, we will cover the biology of epigenetics, how proteins sitting on DNA orchestrate the regulation of genes. In parallel, programming assignments and a project focusing on the analysis of a primary genomic dataset will teach principles of computational biology and their applications to neuroscience. The course material will also serve to demonstrate important concepts in neuroscience, including the diversity of neural cell types, neural plasticity, the role that epigenetics plays in behavior, and how the brain is influenced by neurological and psychiatric disorders. Although the course focuses on neuroscience, the material is accessible and applicable to a wide range of topics in biology.
Prerequisites: (03-121 or 03-151) and (03-221 or 03-220) and (15-112 or 15-121 or 02-201 or 15-110)

02-331 Modeling Evolution

Spring: 12 units
Some of the most serious public health problems we face today, from drug-resistant bacteria, to cancer, all arise from a fundamental property of living systems and #8212; their ability to evolve. Since Darwin's theory of natural selection was first proposed, we have begun to understand how heritable differences in reproductive success drive the adaptation of living systems. This makes it intuitive and tempting to view evolution from an optimization perspective. However, genetic drift, phenotypic trade-offs, constraints, and changing environments, are among the many factors that may limit the optimizing force of natural selection. This tug-of-war between selection and drift, between the forces that produce variation in a population, and the forces suppressing this variation, make evolutionary processes much more complex to model and understand than previously thought. The aim of this class is to provide an introduction into the theoretical formalism necessary to understand how biological systems are shaped by the forces and constraints driving evolutionary dynamics.
Prerequisites: 15-112 and 21-241 and (15-259 or 36-218 or 21-325 or 36-225)

02-402 Computational Biology Seminar

Fall and Spring: 3 units
This course consists of weekly invited presentations on current computational biology research topics by leading scientists. Attendance is mandatory for a passing grade. You must sign in and attend at least 80% of the seminars. See course website for seminar locations. Some will be at the University of Pittsburgh and some will be at Carnegie Mellon.

02-403 Special Topics: Graph Representation Learning in Biology

Intermittent: 12 units
Biological and cellular systems are often modeled as graphs (networks) of interacting elements. This approach has been highly successful owing to the theory, methodology and algorithms that support analysis and learning on graphs. However, recent advances in deep learning techniques have led to a surge in research on graph representation learning. In particular, these advances have led to new state-of-the-art results in biomedicine and healthcare. This course will provide a synthesis and overview of graph representation learning within systems biology and medicine. We will begin with a discussion of the goals of graph representation learning, as well as key methodological foundations in graph theory and network analysis. We next review traditional methods such as topological descriptors, graph kernels, and spectral graph theory. We then introduce techniques for learning node embeddings, including random-walk based methods and applications to knowledge graphs. We finally provide a technical synthesis and introduction to the highly successful graph neural network formalism as well as recent advancements in deep generative models for graphs.
Prerequisites: (02-250 Min. grade C or 03-250 Min. grade C) and 03-121 Min. grade C

02-414 String Algorithms

Intermittent: 12 units
Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous amounts of collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Borrows-Wheeler transform. Applications of these techniques in genomics will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases.
Prerequisites: 15-127 or 15-151 or 21-128

02-421 Algorithms for Computational Structural Biology

Intermittent: 12 units
Some of the most interesting and difficult challenges in computational biology and bioinformatics arise from the determination, manipulation, or exploitation of molecular structures. This course will survey these challenges and present a variety of computational methods for addressing them. Topics will include: molecular dynamics simulations, computer-aided drug design, and computer-aided protein design. The course is appropriate for both students with backgrounds in computer science and those in the life sciences.

02-425 Computational Methods for Proteogenomics and Metabolomics

Spring: 9 units
Proteomics and metabolomics are the large scale study of proteins and metabolites, respectively. In contrast to genomes, proteomes and metabolomes vary with time and the specific stress or conditions an organism is under. Applications of proteomics and metabolomics include determination of protein and metabolite functions (including in immunology and neurobiology) and discovery of biomarkers for disease. These applications require advanced computational methods to analyze experimental measurements, create models from them, and integrate with information from diverse sources. This course specifically covers computational mass spectrometry, structural proteomics, proteogenomics, metabolomics, genome mining and metagenomics.
Prerequisites: 02-250 or 02-604 or 02-251

02-450 Automation of Scientific Research

Spring: 9 units
Automated scientific instruments are used widely in research and engineering. Robots dramatically increase the reproducibility of scientific experiments, and are often cheaper and faster than humans, but are most often used to execute brute-force sweeps over experimental conditions. The result is that many experiments are "wasted" on conditions where the effect could have been predicted. Thus, there is a need for computational techniques capable of selecting the most informative experiments. This course will introduce students to techniques from Artificial Intelligence and Machine Learning for automatically selecting experiments to accelerate the pace of discovery and to reduce the overall cost of research. Real-world applications from Biology, Bioengineering, and Medicine will be studied. Grading will be based on homeworks and two exams. The course is intended to be self-contained, but students should have a basic knowledge of biology, programming, statistics, and machine learning.
Prerequisites: (10-701 or 10-315) and 15-122

02-499 Independent Study in Computational Biology

Fall and Spring
The student will, under the individual guidance of a faculty member, read and digest process papers or a textbook in an advanced area of computational biology not offered by an existing course at Carnegie Mellon. The student will demonstrate their mastery of the material by a combination of one or more of the following: oral discussions with the faculty member; exercises set by the faculty member accompanying the readings; and a written summary synthesizing the material that the student learned. Permission required.

02-500 Undergraduate Research in Computational Biology

Fall and Spring
This course is for undergraduate students who wish to do supervised research for academic credit with a Computational Biology faculty member. Interested students should first contact the Professor with whom they would like to work. If there is mutual interest, the Professor will direct you to the Academic Programs Coordinator who will enroll you in the course. 02-250 is a suggested pre-requisite.

Course Website: https://forms.gle/S1AJX65btkTxwNCw9 (https://forms.gle/S1AJX65btkTxwNCw9/)

02-510 Computational Genomics

Spring: 12 units
Dramatic advances in experimental technology and computational analysis are fundamentally transforming the basic nature and goal of biological research. The emergence of new frontiers in biology, such as evolutionary genomics and systems biology is demanding new methodologies that can confront quantitative issues of substantial computational and mathematical sophistication. From the computational side this course focuses on modern machine learning methodologies for computational problems in molecular biology and genetics, including probabilistic modeling, inference and learning algorithms, data integration, time series analysis, active learning, etc. This course counts as a CSD Applications elective
Prerequisites: 15-122 Min. grade C and (36-235 or 36-218 or 15-259 or 36-225)

02-512 Computational Methods for Biological Modeling and Simulation

Fall: 9 units
This course covers a variety of computational methods important for modeling and simulation of biological systems. It is intended for graduates and advanced undergraduates with either biological or computational backgrounds who are interested in developing computer models and simulations of biological systems. The course will emphasize practical algorithms and algorithm design methods drawn from various disciplines of computer science and applied mathematics that are useful in biological applications. The general topics covered will be models for optimization problems, simulation and sampling, and parameter tuning. Course work will include problem sets with significant programming components and independent or group final projects.
Prerequisites: (15-259 or 36-225 or 36-235 or 36-219 or 21-325 or 36-218 or 36-217) and (21-240 or 21-242 or 21-241) and (02-201 or 15-110 or 15-112) and 21-121

02-514 String Algorithms

Fall: 12 units
Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Burrows-Wheeler transform. Applications of these techniques in biology will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases. No knowledge of biology is assumed, and the topics covered will be of use in other fields involving large collections of strings. Programming proficiency is required.
Prerequisite: 15-251

02-515 Advanced Topics in Computational Genomics

Spring: 12 units
Research in biology and medicine is undergoing a revolution due to the availability of high-throughput technology for probing various aspects of a cell at a genome-wide scale. The next-generation sequencing technology is allowing researchers to inexpensively generate a large volume of genome sequence data. In combination with various other high-throughput techniques for epigenome, transcriptome, and proteome, we have unprecedented opportunities to answer fundamental questions in cell biology and understand the disease processes with the goal of finding treatments in medicine. The challenge in this new genomic era is to develop computational methods for integrating different data types and extracting complex patterns accurately and efficiently from a large volume of data. This course will discuss computational issues arising from high-throughput techniques recently introduced in biology, and cover very recent developments in computational genomics and population genetics, including genome structural variant discovery, association mapping, epigenome analysis, cancer genomics, and transcriptome analysis. The course material will be drawn from very recent literature. Grading will be based on weekly write-ups for ciritiques of the papers to be discussed in the class, class participation, and a final project. It assumes a basic knowledge of machine learning and computational genomics.

02-518 Computational Medicine

Fall: 12 units
Modern medical research increasingly relies on the analysis of large patient datasets to enhance our understanding of human diseases. This course will focus on the computational problems that arise from studies of human diseases and the translation of research to the bedside to improve human health. The topics to be covered include computational strategies for advancing personalized medicine, pharmacogenomics for predicting individual drug responses, metagenomics for learning the role of the microbiome in human health, mining electronic medical records to identify disease phenotypes, and case studies in complex human diseases such as cancer and asthma. We will discuss how machine learning methodologies such as regression, classification, clustering, semi-supervised learning, probabilistic modeling, and time-series modeling are being used to analyze a variety of datasets collected by clinicians. Class sessions will consist of lectures, discussions of papers from the literature, and guest presentations by clinicians and other domain experts. Grading will be based on homework assignments and a project. 02-250 is a suggested pre-requisite.

Course Website: https://sites.google.com/view/computationalmedicine/

02-530 Cell and Systems Modeling

Fall: 12 units
This course will introduce students to the theory and practice of modeling biological systems from the molecular to the organism level with an emphasis on intracellular processes. Topics covered include kinetic and equilibrium descriptions of biological processes, systematic approaches to model building and parameter estimation, analysis of biochemical circuits modeled as differential equations, modeling the effects of noise using stochastic methods, modeling spatial effects, and modeling at higher levels of abstraction or scale using logical or agent-based approaches. A range of biological models and applications will be considered including gene regulatory networks, cell signaling, and cell cycle regulation. Weekly lab sessions will provide students hands-on experience with methods and models presented in class. Course requirements include regular class participation, bi-weekly homework assignments, a take-home exam, and a final project. The course is designed for graduate and upper-level undergraduate students with a wide variety of backgrounds. The course is intended to be self-contained but students may need to do some additional work to gain fluency in core concepts. Students should have a basic knowledge of calculus, differential equations, and chemistry as well as some previous exposure to molecular biology and biochemistry. Experience with programming and numerical computation is useful but not mandatory. Laboratory exercises will use MATLAB as the primary modeling and computational tool augmented by additional software as needed.
Prerequisites: (33-121 or 03-151 or 03-121) and (03-231 or 03-232) and 21-112 and 09-105

02-540 Bioimage Informatics

Intermittent: 12 units
With the rapid advance of bioimaging techniques and fast accumulation of bioimage data, computational bioimage analysis and modeling are playing an increasingly important role in understanding of complex biological systems. The goals of this course are to provide students with the ability to understand a broad set of practical and cutting-edge computational techniques to extract knowledge from bioimages.
Prerequisites: 02-620 or 10-301 or 10-701 or 10-601 or 10-315

02-601 Programming for Scientists

Fall and Spring: 12 units
Provides a practical introduction to programming for students with little previous programming experience who are interested in science. Fundamental scientific algorithms will be introduced, and extensive programming assignments will be based on analytical tasks that might be faced by scientists, such as parsing, simulation, and optimization. Principles of good software engineering will also be stressed. The course will introduce students to the Go programming language, an industry-supported, modern programming language, the syntax of which will be covered in depth. Other assignments may be given in other programming languages to highlight the commonalities and differences between languages. No biology background is needed. Analytical skills, an understanding of programming basics, and mathematical maturity are required. A preparatory self-paced bootcamp on programming basics is provided to students to complete before beginning the course

02-602 Professional Issues for Computational and Automated Scientists

Fall and Spring: 3 units
This course gives Master's in Computational Biology and Master's in Automated Science students the opportunity to develop the professional skills necessary for a successful career in either academia or industry. This course, required in the first semester of both programs, will include assistance with elevator pitches, interview preparation, resume and cover letter writing, networking, and presentation skills. The course will also include opportunities to connect with computational biology professionals as part of industry outreach. The course will meet once a week and is pass/fail only.

02-604 Fundamentals of Bioinformatics

Spring: 12 units
How do we find potentially harmful mutations in your genome? How can we reconstruct the Tree of Life? How do we compare similar genes from different species? These are just three of the many central questions of modern biology that can only be answered using computational approaches. This 12-unit course will delve into some of the fundamental computational ideas used in biology and let students apply existing resources that are used in practice every day by thousands of biologists. The course offers an opportunity for students who possess an introductory programming background to become more experienced coders within a biological setting. As such, it presents a natural next course for students who have completed 02-601.

02-605 Professional Issues in Automated Science

Spring: 3 units
This course gives MS in Automated Science students an opportunity to develop professional skills necessary for a successful career in computational biology. This course will include assistance with resume writing, interview preparation, presentation skills, and job search techniques. This course will also include opportunities to network with computational biology professionals and academic researchers.

02-613 Algorithms and Advanced Data Structures

Fall and Spring: 12 units
The objective of this course is to study algorithms for general computational problems, with a focus on the principles used to design those algorithms. Efficient data structures will be discussed to support these algorithmic concepts. Topics include: Run time analysis, divide-and-conquer algorithms, dynamic programming algorithms, network flow algorithms, linear and integer programming, large-scale search algorithms and heuristics, efficient data storage and query, and NP-completeness. Although this course may have a few programming assignments, it is primarily not a programming course. Instead, it will focus on the design and analysis of algorithms for general classes of problems. This course is not open to CS graduate students who should consider taking 15-651 instead. 02-250 is a suggested prerequisite for undergraduates.

02-614 String Algorithms

Intermittent: 12 units
Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous amounts of collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Borrows-Wheeler transform. Applications of these techniques in genomics will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases.
Prerequisites: 15-151 or 15-127 or 21-128

02-620 Machine Learning for Scientists

Spring: 12 units
With advances in scientific instruments and high-throughput technology, scientific discoveries are increasingly made from analyzing large-scale data generated from experiments or collected from observational studies. Machine learning methods that have been widely used to extract complex patterns from large speech, text, and image data are now being routinely applied to answer scientific questions in biology, bioengineering, and medicine. This course is intended for graduate students interested in learning machine learning methods for scientific data analysis and modeling. It will cover classification and regression techniques such a logistic regression, random forest regression, Gaussian process regression, decision trees, and support vector machines; unsupervised learning methods such as clustering algorithms, mixture models, and hidden Markov models; probabilistic graphical models and deep learning methods; and learning theories such as PAC learning and VC dimension. The course will focus on applications of these methods in genomics and medicine. Programming skills and basic knowledge of linear algebra, probability, statistics are assumed.
Prerequisite: 02-680

02-651 New Technologies and Future Markets

Fall: 12 units
This course focuses on technological trends and how these trends can help shape or disrupt new and existing markets. Students will learn to identify, analyze, and synthesize emerging trends and perform detailed research on how these trends can influence and create markets. By understand the drivers behind these trends students will be able to identify key market opportunity inflection points in biotechnology as well as the relationship between business processes and information technology (IT). Students will also learn to assess some information technologies and the potential of applying them to solve problems and create commercially viable solutions. The course is designed for the student interested in finding new venture opportunities on the cutting edge of technology and finding and evaluating the opportunities for further development. For MS Biotechnology Innovation and Computation students only.
Prerequisite: 11-695

02-654 Biotechnology Enterprise Development

Fall: 12 units
In this course students learn how to develop a biotech start-up, create a Minimum Viable Product (MVP), business model and strategy for the product. Students will learn about business modeling, customer development, customer validation, proposal, product branding, and marketing for their product. The course will require students to spend most time to validate their start up concept and prototypes with potential customers and adapt to critical feedback and revise their respective value propositions accordingly. Students learn to balance technical product development with customer requirements, business strategy and budget constraints. This course provides real world, hands-on learning on what it is like to start a company. Different business modeling will be covered. By understand customer discovery and validation concepts will aid students to effectively modify their original concepts to meet market demands. Student teams will learn how to revise, improve their prototype by the end of the term. This is a fast paced course in which students are expected to spend most of the time outside of the classroom to interact with potential customers to validate, test, verify, and integrate essentials elements for their start-up business proposal. Up to now, students have been learning some technologies and methods for solving problems in the life science industry and build a prototype for their start-up. However, a new venture proposal is not a collection of isolated bits. It should be thorough validated via customer's inputs and market needs to tell a single story of how the venture will reach its end goals. Final deliverable is creation and presentation of a well explicated, business proposal in addition to a product prototype corresponding to the business proposal.
Prerequisites: 02-651 and 11-695

02-680 Essential Mathematics and Statistics for Scientists

Fall: 9 units
This course rigorously introduces fundamental topics in mathematics and statistics to first-year master's students as preparation for more advanced computational coursework. Topics are sampled from information theory, graph theory, proof techniques, phylogenetics, combinatorics, set theory, linear algebra, neural networks, probability distributions and densities, multivariate probability distributions, maximum likelihood estimation, statistical inference, hypothesis testing, Bayesian inference, and stochastic processes. Students completing this course will obtain a broad skillset of mathematical techniques and statistical inference as well as a deep understanding of mathematical proof. They will have the quantitative foundation to immediately step into an introductory master's level machine learning or automation course. This background will also serve students well in advanced courses that apply concepts in machine learning to scientific datasets, such as 02-710 (Computational Genomics) or 02-750 (Automation of Biological Research). The course grade will be computed as the result of homework assignments, midterm tests, and class participation.

02-699 Independent Study in Computational Biology

Fall and Spring
The student will, under the individual guidance of a faculty member, read and digest process papers or a textbook in an advanced area of computational biology not offered by an existing course at Carnegie Mellon. The student will demonstrate their mastery of the material by a combination of one or more of the following: oral discussions with the faculty member; exercises set by the faculty member accompanying the readings; and a written summary synthesizing the material that the student learned. Permission required.

02-700 M.S. Thesis Research

Fall and Spring
This course is for M.S. students who wish to do supervised research for academic credit with a Computational Biology faculty member. Interested students should first contact the Professor with whom they would like to work. If there is mutual interest, the Professor will direct you to the Academic Programs Coordinator, who will enroll you in the course.

Course Website: https://forms.gle/tDKDs1EujvXAApYK7 (https://forms.gle/tDKDs1EujvXAApYK7/)

02-702 Computational Biology Seminar

Fall and Spring: 3 units
This course consists of weekly invited presentations on current computational biology research topics by leading scientists. Attendance is mandatory for a passing grade. You must sign in and attend at least 80 percent of the seminars. See course website for seminar locations. Some will be at the University of Pittsburgh and some will be at Carnegie Mellon.

Course Website: https://www.compbio.cmu.edu/seminar-series/index.html (https://www.compbio.cmu.edu/seminar-series/)

02-703 Special Topics: Graph Representation Learning in Biology

Intermittent: 12 units
Biological and cellular systems are often modeled as graphs (networks) of interacting elements. This approach has been highly successful owing to the theory, methodology and algorithms that support analysis and learning on graphs. However, recent advances in deep learning techniques have led to a surge in research on graph representation learning. In particular, these advances have led to new state-of-the-art results in biomedicine and healthcare. This course will provide a synthesis and overview of graph representation learning within systems biology and medicine. We will begin with a discussion of the goals of graph representation learning, as well as key methodological foundations in graph theory and network analysis. We next review traditional methods such as topological descriptors, graph kernels, and spectral graph theory. We then introduce techniques for learning node embeddings, including random-walk based methods and applications to knowledge graphs. We finally provide a technical synthesis and introduction to the highly successful graph neural network formalism as well as recent advancements in deep generative models for graphs.

02-704 Special Topics: Introduction to Statistical Genetics

Intermittent: 12 units
This course will cover quantitative topics in human statistical genetics, including the HapMap project, linkage disequilibrium, population structure and stratification, natural selection, genome-wide association studies, estimating and partitioning heritability, association testing, statistical fine-mapping, disease gene mapping, expression quantitative trait loci, single-cell genomics, and polygenic risk prediction. The course will emphasize hands-on analysis of large empirical data sets, thus requiring prior experience with a general-purpose high-level programming language such as Python. After taking this course, each student will have the experience and skills to develop and apply statistical methods to population genetic data.
Prerequisites: (02-601 or 15-112) and (02-680 or 36-226 or 36-236 or 15-259 or 15-260 or 36-218)

02-710 Computational Genomics

Spring: 12 units
Dramatic advances in experimental technology and computational analysis are fundamentally transforming the basic nature and goal of biological research. The emergence of new frontiers in biology, such as evolutionary genomics and systems biology is demanding new methodologies that can confront quantitative issues of substantial computational and mathematical sophistication. From the computational side this course focuses on modern machine learning methodologies for computational problems in molecular biology and genetics, including probabilistic modeling, inference and learning algorithms, data integration, time series analysis, active learning, etc. This course counts as a CSD Applications elective

02-711 Computational Molecular Biology and Genomics

Spring: 12 units
An advanced introduction to computational molecular biology, using an applied algorithms approach. The first part of the course will cover established algorithmic methods, including pairwise sequence alignment and dynamic programming, multiple sequence alignment, fast database search heuristics, hidden Markov models for molecular motifs and phylogeny reconstruction. The second part of the course will explore emerging computational problems driven by the newest genomic research. Course work includes four to six problem sets, one midterm and final exam.
Prerequisites: (03-121 or 03-151) and 15-122

02-712 Computational Methods for Biological Modeling and Simulation

Fall: 12 units
This course covers a variety of computational methods important for modeling and simulation of biological systems. It is intended for graduates and advanced undergraduates with either biological or computational backgrounds who are interested in developing computer models and simulations of biological systems. The course will emphasize practical algorithms and algorithm design methods drawn from various disciplines of computer science and applied mathematics that are useful in biological applications. The general topics covered will be models for optimization problems, simulation and sampling, and parameter tuning. Course work will include problem sets with significant programming components and independent or group final projects.
Prerequisites: (02-601 or 15-112 or 15-110) and (15-259 or 21-325 or 36-218 or 36-219 or 02-680 or 36-217 or 36-235 or 36-225)

02-714 String Algorithms

Fall: 12 units
Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Borrows-Wheeler transform. Applications of these techniques in biology will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases. No knowledge of biology is assumed, and the topics covered will be of use in other fields involving large collections of strings. Programming proficiency is required.
Prerequisite: 15-251

02-715 Advanced Topics in Computational Genomics

Spring: 12 units
Research in biology and medicine is undergoing a revolution due to the availability of high-throughput technology for probing various aspects of a cell at a genome-wide scale. The next-generation sequencing technology is allowing researchers to inexpensively generate a large volume of genome sequence data. In combination with various other high-throughput techniques for epigenome, transcriptome, and proteome, we have unprecedented opportunities to answer fundamental questions in cell biology and understand the disease processes with the goal of finding treatments in medicine. The challenge in this new genomic era is to develop computational methods for integrating different data types and extracting complex patterns accurately and efficiently from a large volume of data. This course will discuss computational issues arising from high-throughput techniques recently introduced in biology, and cover very recent developments in computational genomics and population genetics, including genome structural variant discovery, association mapping, epigenome analysis, cancer genomics, and transcriptome analysis. The course material will be drawn from very recent literature. Grading will be based on weekly write-ups for cirtiques of the papers to be discussed in the class, class participation, and a final project. It assumes a basic knowledge of machine learning and computational genomics.

02-717 Algorithms in Nature

Fall: 12 units
Computer systems and biological processes often rely on networks of interacting entities to reach joint decisions, coordinate and respond to inputs. There are many similarities in the goals and strategies of biological and computational systems which suggest that each can learn from the other. These include the distributed nature of the networks (in biology molecules, cells, or organisms often operate without central control), the ability to successfully handle failures and attacks on a subset of the nodes, modularity and the ability to reuse certain components or sub-networks in multiple applications and the use of stochasticity in biology and randomized algorithms in computer science. In this course we will start by discussing classic biologically motivated algorithms including neural networks (inspired by the brain), genetic algorithms (sequence evolution), non-negative matrix factorization (signal processing in the brain), and search optimization (ant colony formation). We will then continue to discuss more recent bi-directional studies that have relied on biological processes to solve routing and synchronization problems, discover Maximal Independent Sets (MIS), and design robust and fault tolerant networks. In the second part of the class students will read and present new research in this area. Students will also work in groups on a final project in which they develop and test a new biologically inspired algorithm. See also: www.algorithmsinnature.org no prior biological knowledge required.

02-718 Computational Medicine

Fall: 12 units
Modern medical research increasingly relies on the analysis of large patient datasets to enhance our understanding of human diseases. This course will focus on the computational problems that arise from studies of human diseases and the translation of research to the bedside to improve human health. The topics to be covered include computational strategies for advancing personalized medicine, pharmacogenomics for predicting individual drug responses, metagenomics for learning the role of the microbiome in human health, mining electronic medical records to identify disease phenotypes, and case studies in complex human diseases such as cancer and asthma. We will discuss how machine learning methodologies such as regression, classification, clustering, semi-supervised learning, probabilistic modeling, and time-series modeling are being used to analyze a variety of datasets collected by clinicians. Class sessions will consist of lectures, discussions of papers from the literature, and guest presentations by clinicians and other domain experts. Grading will be based on homework assignments and a project. 02-250 is a suggested pre-requisite.
Prerequisites: 10-315 or (10-701 and 10-601 and 10-401)

Course Website: https://sites.google.com/view/computationalmedicine/

02-719 Genomics and Epigenetics of the Brain

Fall: 12 units
This course will provide an introduction to genomics, epigenetics, and their application to problems in neuroscience. The rapid advances in single cell sequencing and other genomic technologies are revolutionizing how neuroscience research is conducted, providing tools to study how different cell types in the brain produce behavior and contribute to neurological disorders. Analyzing these powerful new datasets requires a foundation in molecular neuroscience as well as key computational biology techniques. In this course, we will cover the biology of epigenetics, how proteins sitting on DNA orchestrate the regulation of genes. In parallel, programming assignments and a project focusing on the analysis of a primary genomic dataset will teach principles of computational biology and their applications to neuroscience. The course material will also serve to demonstrate important concepts in neuroscience, including the diversity of neural cell types, neural plasticity, the role that epigenetics plays in behavior, and how the brain is influenced by neurological and psychiatric disorders. Although the course focuses on neuroscience, the material is accessible and applicable to a wide range of topics in biology.
Prerequisites: (03-121 or 03-151) and 03-220 and (15-110 or 15-121 or 02-201)

02-721 Algorithms for Computational Structural Biology

Intermittent: 12 units
Some of the most interesting and difficult challenges in computational biology and bioinformatics arise from the determination, manipulation, or exploitation of molecular structures. This course will survey these challenges and present a variety of computational methods for addressing them. Topics will include: molecular dynamics simulations, computer-aided drug design, and computer-aided protein design. The course is appropriate for both students with backgrounds in computer science and those in the life sciences.

02-725 Computational Methods for Proteogenomics and Metabolomics

Spring: 12 units
Proteomics and metabolomics are the large scale study of proteins and metabolites, respectively. In contrast to genomes, proteomes and metabolomes vary with time and the specific stress or conditions an organism is under. Applications of proteomics and metabolomics include determination of protein and metabolite functions (including in immunology and neurobiology) and discovery of biomarkers for disease. These applications require advanced computational methods to analyze experimental measurements, create models from them, and integrate with information from diverse sources. This course specifically covers computational mass spectrometry, structural proteomics, proteogenomics, metabolomics, genome mining and metagenomics.
Prerequisites: 02-250 or 02-251 or 02-604

02-730 Cell and Systems Modeling

Fall: 12 units
This course will introduce students to the theory and practice of modeling biological systems from the molecular to the organism level with an emphasis on intracellular processes. Topics covered include kinetic and equilibrium descriptions of biological processes, systematic approaches to model building and parameter estimation, analysis of biochemical circuits modeled as differential equations, modeling the effects of noise using stochastic methods, modeling spatial effects, and modeling at higher levels of abstraction or scale using logical or agent-based approaches. A range of biological models and applications will be considered including gene regulatory networks, cell signaling, and cell cycle regulation. Weekly lab sessions will provide students hands-on experience with methods and models presented in class. Course requirements include regular class participation, bi-weekly homework assignments, a take-home exam, and a final project. The course is designed for graduate and upper-level undergraduate students with a wide variety of backgrounds. The course is intended to be self-contained but students may need to do some additional work to gain fluency in core concepts. Students should have a basic knowledge of calculus, differential equations, and chemistry as well as some previous exposure to molecular biology and biochemistry. Experience with programming and numerical computation is useful but not mandatory. Laboratory exercises will use MATLAB as the primary modeling and computational tool augmented by additional software as needed. *THIS COURSE WILL BE AT PITT
Prerequisites: (33-121 or 03-121 or 03-151) and (03-231 or 03-232) and 21-112 and 09-105

Course Website: https://sites.google.com/site/cellandsystemsmodeling/

02-731 Modeling Evolution

Spring: 12 units
Some of the most serious public health problems we face today, from drug-resistant bacteria, to cancer, all arise from a fundamental property of living systems and #8212; their ability to evolve. Since Darwin's theory of natural selection was first proposed, we have begun to understand how heritable differences in reproductive success drive the adaptation of living systems. This makes it intuitive and tempting to view evolution from an optimization perspective. However, genetic drift, phenotypic trade-offs, constraints, and changing environments, are among the many factors that may limit the optimizing force of natural selection. This tug-of-war between selection and drift, between the forces that produce variation in a population, and the forces suppressing this variation, make evolutionary processes much more complex to model and understand than previously thought. The aim of this class is to provide an introduction into the theoretical formalism necessary to understand how biological systems are shaped by the forces and constraints driving evolutionary dynamics.
Prerequisites: 15-112 and 21-241 and (36-225 or 15-259 or 36-218 or 21-325)

02-740 Bioimage Informatics

Intermittent: 12 units
With the rapid advance of bioimaging techniques and fast accumulation of bioimage data, computational bioimage analysis and modeling are playing an increasingly important role in understanding of complex biological systems. The goals of this course are to provide students with the ability to understand a broad set of practical and cutting-edge computational techniques to extract knowledge from bioimages.

02-750 Automation of Scientific Research

Spring: 12 units
Automated scientific instruments are used widely in research and engineering. Robots dramatically increase the reproducibility of scientific experiments, and are often cheaper and faster than humans, but are most often used to execute brute-force sweeps over experimental conditions. The result is that many experiments are "wasted" on conditions where the effect could have been predicted. Thus, there is a need for computational techniques capable of selecting the most informative experiments. This course will introduce students to techniques from Artificial Intelligence and Machine Learning for automatically selecting experiments to accelerate the pace of discovery and to reduce the overall cost of research. Real-world applications from Biology, Bioengineering, and Medicine will be studied. Grading will be based on homeworks and two exams. The course is intended to be self-contained, but students should have a basic knowledge of biology, programming, statistics, and machine learning.
Prerequisites: 10-601 or 10-701 or 02-620

02-760 Laboratory Methods for Computational Biologists

Fall and Spring: 9 units
Computational biologists frequently focus on analyzing and modeling large amounts of biological data, often from high-throughput assays or diverse sources. It is therefore critical that students training in computational biology be familiar with the paradigms and methods of experimentation and measurement that lead to the production of these data. This one-semester laboratory course gives students a deeper appreciation of the principles and challenges of biological experimentation. Students learn a range of topics, including experimental design, structural biology, next generation sequencing, genomics, proteomics, bioimaging, and high-content screening. Class sessions are primarily devoted to designing and performing experiments in the lab using the above techniques. Students are required to keep a detailed laboratory notebook of their experiments and summarize their resulting data in written abstracts and oral presentations given in class-hosted lab meetings. With an emphasis on the basics of experimentation and broad views of multiple cutting-edge and high-throughput techniques, this course is appropriate for students who have never taken a traditional undergraduate biology lab course, as well as those who have and are looking for introductory training in more advanced approaches. Grading: Letter grade based on class participation, laboratory notebooks, experimental design assignments, and written and oral presentations. 02-250 is a suggested pre-requisite.

02-761 Laboratory Methods for Automated Biology I

Fall: 12 units
In order to rapidly generate reproducible experimental data, many modern biology labs leverage some form of laboratory automation to execute experiments. In the not so distant future, the use of laboratory automation will continue to increase in the biological lab to the point where many labs will be fully automated. Therefore, it is critical for automation scientists to be familiar with the principles, experimental paradigms, and techniques for automating biological experimentation with an eye toward the fully automated laboratory. In this laboratory course, students will learn about various automatable experimental methods, design of experiments, hardware for preparing samples and executing automated experiments, and software for controlling that hardware. These topics will be taught in lectures as well as through laboratory experience using multi-purpose laboratory robotics. During weekly laboratory time, students will complete and integrate parts of two larger projects. The first project will be focused on liquid handling, plate control, plate reading, and remote control of the automated system based on experimental data. The second project will be focused on the design, implementation, and analysis of a high content screening campaign using fluorescence microscopy, image analysis, and tissue culture methods.

02-762 Laboratory Methods for Automated Biology II

Spring: 12 units
This laboratory course provides a continuation and extension of experiences in 02-761. Instruction will consist of lectures and laboratory experience using multi-purpose laboratory robotics. During weekly laboratory time, students will complete and integrate parts of two larger projects. The first project will be focused on the execution of a molecular biology experiment requiring nucleic acid extraction, library preparation for sequencing, and quality control. The second project will be focused on the implementation and execution of automated methods using active learning techniques to direct the learning of a predictive model for a large experimental space (such as learning the effects of many possible drugs on many possible targets). Grading will be based on lab and project completion and quality.
Prerequisite: 02-761

02-764 Automated Science Capstone II

Spring: 12 units
This course consists of small group projects on development, implementation and/or execution of automated science campaigns in collaboration with industry and/or academic partners. This course may only be taken as part of a continuous sequence with 02-763. Enrollment is only open to M.S. in Automated Science students.

Human-Computer Interaction Courses

05-090 Human-Computer Interaction Practicum

All Semesters: 3 units
This course is for HCII students who wish to have an internship experience as part of their curriculum. Students are required to write a one-page summary statement prior to registration that explains how their internship connects with their HCI curriculum, specifically on how it uses material they have learned as well as prepares them for future courses. Near the end of the internship, students will be required to submit a reflection paper that describes the work they did in more detail, including lessons learned about the work experience and how they utilized their HCI education to work effectively. International students should consult with the Office of International Education for appropriate paperwork and additional requirements before registration. Units earned count toward the total required units necessary for degree completion; students should speak with an academic advisor for details. This course may be taken at most 3 times for a total of 9 units maximum. Students normally register for this course for use during the summer semester.

05-180 Introduction to Human-Computer Interaction

Spring: 5 units
This course is for first-year students who are interested in learning more about HCI, especially first-year SCS students considering the primary HCI major.

05-200 Ethics and Policy Issues in Computing

Intermittent: 9 units
Should autonomous robots make life and death decisions on their own? Should we allow them to select a target and launch weapons? To diagnose injuries and perform surgery when human doctors are not around? Who should be permitted to observe you, find out who your friends are, what you do and say with them, what you buy, and where you go? Do social media and personalized search restrict our intellectual horizons? Do we live in polarizing information bubbles, just hearing echoes of what we already know and believe? As computing technology becomes ever more pervasive and sophisticated, we are presented with an escalating barrage of decisions about who, how, when, and for what purposes technology should be used. This course will provide an intellectual framework for discussing these pressing issues of our time, as we shape the technologies that in turn shape us. We will seek insight through reading, discussion, guest lectures, and debates. Students will also undertake an analysis of a relevant issue of their choice, developing their own position, and acquiring the research skills needed to lend depth to their thinking. The course will enhance students' ability to think clearly about contentious technology choices, formulate smart positions, and support their views with winning arguments.

05-291 Learning Media Design

Fall: 12 units
[IDeATe collaborative course] Learning is a complex human phenomenon with cognitive, social and personal dimensions that need to be accounted for in the design of technology enhanced learning experiences. In this studio course students will apply learning science concepts to critique existing forms of learning media, establish a set of design precedents to guide project work and produce a series of design concepts that support learning interactions in a real-world context. Collaborating in small interdisciplinary teams, students will partner with a local informal learning organization (e.g. museum, after school program provider, maker space) to conduct learning design research studies, synthesize findings, establish learning goals and iteratively prototype and assess design concepts. As final deliverables, students will present their design research findings, design concepts, and prototypes to stakeholders, and draft a media-rich proposal for their learning media concept to pitch to a local funder. Please note that there may be usage/materials fees associated with this course. Please note that there may be usage/materials fees associated with this course.

05-292 IDeATe: Learning in Museums

Spring: 12 units
Learning in Museums brings together students from across the disciplines to consider the design of mediated learning experiences though a project-based inquiry course. Students will be introduced to a range of design research methods and associated frameworks that explore the cognitive, social and affective dimensions of learning in everyday contexts through readings, invited lectures, in-class activities and assignments. Students will conduct a series of short design research studies to define learning goals and develop supporting design concepts that improve learning outcomes for diverse participants in informal learning settings (e.g. museums, after school programs, maker spaces or online). In concept development, we will look at how to position technology and question its role in the setting to engage and foster positive learning interactions. This course will culminate in a media-rich presentation of design concepts and a prototype to a stakeholder audience, and include an evaluation plan describing how learning outcomes for the project would be assessed.

05-300 HCI Undergraduate Pro Seminar

All Semesters: 2 units
HCI is a broad field that brings together approaches from design, computer science, and psychology. This course provides an introduction to the field of HCI and to the HCI community at CMU. Guest speakers from around campus will provide a general introduction to these approaches and how they are pursued at CMU, and will describe research opportunities that are available to undergraduates. The course will also discuss career options in both industry and academia for students of HCI, and will include presentations from HCI alumni and sessions on preparing resumes, creating portfolios, and interviewing for jobs. The course is designed for current or potential HCI majors and minors but is open to anyone with an interest in applying for the HCI major/minor.

Course Website: https://hcii.cmu.edu/academics/courses (https://hcii.cmu.edu/academics/courses/)

05-315 Persuasive Design

Fall: 12 units
This project-based course focuses on the ethical, human-centered design and evaluation of persuasive technologies that aim to change users' attitudes, emotions, or behaviors in ways that benefit the self and/or society. In addition to exposing students to an array of psychological theories and strategies for implicit and explicit persuasion, the course will cover a variety of topics illustrating both the pitfalls and possibilities in designing for positive impact in HCI. The focal point of the class will be the semester project, for which student teams will iteratively conceptualize, prototype, implement, and evaluate a tool, system, or change to a ubiquitous computing environment that intends to stimulate and sustain belief or behavior change (such as reducing cognitive or social biases, building healthy or prosocial habits, or resisting other persuasive forces one encounters on a daily basis).

05-317 Design of Artificial Intelligence Products

Intermittent: 12 units
This course teaches students how to design new products and services that leverage the capabilities of AI and machine learning to improve the quality of peoples lives. Students will learn to follow a matchmaking design, user-centered design, and service design process. Students will learn to ideate; reframing problematic situations by envisioning many possible products and services. Students will learn to iteratively refine and assess their ideas with real users/customers. Class projects will focus on the challenges of deploying systems that generate errors and the challenges of situating intelligent systems such that they harmonize the best qualities of human and machine intelligence.

Course Website: https://hcii.cmu.edu/academics/courses (https://hcii.cmu.edu/academics/courses/)

05-318 Human AI Interaction

Intermittent: 12 units
Artificial Intelligence is inspired by human intelligence, made powerful by human data, and ultimately only useful in how it positively affects the human experience. This course is an introduction to harnessing the power of AI so that it is beneficial and useful to people. We will cover a number of general topics: agency and initiative, AI and ethics, bias and transparency, confidence and errors, human augmentation and amplification, trust and explainability, mixed-initiative systems, and programming by example. These topics will be explored via projects in dialog and speech-controlled systems, automatic speech recognition, computer vision, data science, recommender systems, text summarization, learning science, UI personalization, and visualization. Students will complete individual weekly mini-projects in which they will design and build AI systems across a wide variety of domains. Students should be comfortable with programming; assignments will be primarily in Python and Javascript. Prior experience with AI/machine learning will be useful but is not required. Students will also be responsible for weekly readings and occasional presentations to the class.

Course Website: http://www.hcii.cmu.edu/academics/courses (http://www.hcii.cmu.edu/academics/courses/)

05-319 Data Visualization

Fall: 12 units
This course is an introduction to key design principles and techniques for interactively visualizing data. The major goals of this course are to understand how visual representations can help in the analysis and understanding of complex data, how to design effective visualizations, and how to create your own interactive visualizations using modern web-based frameworks.

Course Website: https://dig.cmu.edu/courses/2022-fall-datavis.html

05-320 Social Web

Intermittent: 12 units
With the growth of online environments like MySpace, Second Life, World of Warcraft, Wikipedia, blogs, online support groups, and open source development communities, the web is no longer just about information. This course, jointly taught by a computer scientist and a behavioral scientist, will examine a sampling of the social, technical and business challenges social web sites must solve to be successful, teach students how to use high-level tools to analyze, design or build online communities, and help them understand the social impact of spending at least part of their lives online. This class is open to advanced undergraduates and graduate students with either technical or non-technical backgrounds. Course work will include lectures and class discussion, homework, class presentations, and a group research or design project.

05-321 Transformational Game Design Studio

Fall: 12 units
TBA

05-333 Gadgets, Sensors and Activity Recognition in HCI

Fall: 12 units
Recent advances in HCI have been driven by new capabilities to deliver inexpensive devices to users, to display information in mobile and other contexts, to sense the user and their environment, and use these sensors to create models of a user's context and actions. This course will consider both concepts surrounding these new technological opportunities through discussion of current literature - and practical considerations the skills needed to actually build devices. About 1/3 of this class will review current advances in this area. The remainder will be devoted to development of individual skills so that students leaving the class will have an ability to actually build small devices for human interaction (in short: "HCI gadgets"). In particular, the course will concentrate on the basics of building simple microcontroller-based devices and will also provide very basic coverage of the machine learning techniques needed for simple sensor-driven statistical models. The course is designed to be accessible to students with a wide range of backgrounds including both technically-oriented and non-technical students (especially Designers) interested in HCI. The class will be project oriented with 4-5 electronic prototype building projects during the semester. At least two of these projects will be self-defined in nature and can be adapted to the existing skills and interests of each student. There are no formal prerequisites for this class. However, the class will involve programming and debugging of micro-controllers. Some coverage of the language used to do this will be provided, and if required by your background, the programming component of the projects can be made comparatively small (but, in that case some other aspect of the projects will need to be expanded). However, you should not take this course if you have no programming background. This course assumes no background in electronics.

Course Website: http://www.hcii.cmu.edu/courses/applied-gadgets-sensors-and-activity-recognition-hci (http://www.hcii.cmu.edu/courses/applied-gadgets-sensors-and-activity-recognition-hci/)

05-341 Organizational Communication

All Semesters: 9 units
Most of management is communication. You communicate to get information that will be the basis of decisions, coordinate activity, to provide a vision for the people who work for and with you, to and to sell yourself and your work. The goal of this course is to identify communication challenges within work groups and organizations and ways to overcome them. To do this requires that we know how communication normally works, what parts are difficult, and how to fix it when it goes wrong. The focus of this course is on providing you with a broad understanding of the way communication operates within dyads, work groups, and organizations. The intent is to give you theoretical and empirical underpinnings for the communication you will undoubtedly participate in when you move to a work environment, and strategies for improving communication within your groups. Because technology is changing communication patterns and outcomes both in organizations and more broadly in society, the course examines these technological changes. Readings come primarily from the empirical research literature.

Course Website: http://www.hcii.cmu.edu/courses/organizational-communication (http://www.hcii.cmu.edu/courses/organizational-communication/)

05-360 Interaction Design Fundamentals

Fall and Spring: 12 units
IXD Fundamentals introduces the human-centered design process as well as fundamental interaction design principles, methods, and practices. The course is for both students who may only enroll in one interaction design course and those who intend to build upon their HCI learning by taking advanced interaction design courses. Students must work effectively as individuals and in small teams to learn interaction design concepts and apply them to real-world problems. By the end of this course students should be able to; -Apply appropriate interaction design methods in a human-centered design process. -Create persuasive interim and final design artifacts that demonstrate communication design fundamentals. -Facilitate productive and structured critique across the class and with instructors. -Explain and apply fundamental interaction design principles. -Create clarity and readability in artifacts, including GUIs and deliverables, through the disciplined application of visual design principles such as typography, color and composition. -Practice reframing a given problem in order to create opportunities that drive generating multiple solutions. -Demonstrate habits that foster the creative process, including drawing, divergent thinking, and creative experimentation. -Identify and explore with interaction design materials. This course serves as a prerequisite for Advanced Interaction Design Studio (number TBD). Students who are required to take this course have priority and will be enrolled first. No coding is required.

05-361 Advanced Interaction Design

Spring: 12 units
Advanced Interaction Design follows Interaction Design for Human-Computer Interaction (05-360/05-660). Students are expected to build on the basic interaction design principles they learned in Interaction Design Fundamentals by applying advanced methods to solve more complex problems using emerging technologies in user experiences that cross devices, modalities and contexts. Students learn how to design with advanced technologies that predict, assist and automate, and make through a design system. Systems thinking, data as a design material, and UI design are emphasized in projects which are designed to give students experience solving complex problems that they are likely to encounter as practitioners. Advanced Interaction Design prepares students to become interaction designers that take a rigorous and principled approach to solving enterprise-scale problems where many systems and applications serve many stakeholders.
Prerequisites: 05-392 or 05-651 or 05-360

05-380 Prototyping Algorithmic Experiences

Intermittent: 15 units
This project-based course provides an overview and hands-on introduction to iterative prototyping methods in HCI, with an emphasis on current and emerging technologies such as data-driven algorithmic systems, AI and machine learning, spatial computing, and IoT. Students will learn and implement approaches for creating and using prototypes to iteratively inform the creation of new technologies. The course will help students learn to strategically evaluate whether a given prototyping approach is a good fit for a given design or research question. In addition to HCI undergraduate majors, the course is open to undergraduate and graduate level students with proficiency in programming and prior courses or experience in user-centered research, design, and/or evaluation. Some exceptions to the course prerequisites will be granted with permission of the instructor.
Prerequisites: 15-112 and (15-121 or 15-122 or 15-150 or 15-210) and (05-650 or 05-651 or 05-391 or 05-410 or 05-392 or 05-470 or 05-317 or 05-360 or 05-452)

05-391 Designing Human Centered Software

All Semesters: 12 units
"Why are things so hard to use these days? Why doesn't this thing I just bought work? Why is this web site so hard to use? These are frustrations that we have all faced from systems not designed with people in mind. The question this course will focus on is: how can we design human-centered systems that people find useful and usable? This course is a broad introduction to designing, prototyping, and evaluating user interfaces. If you take only one course in Human-Computer Interaction, this is the course for you. We will cover theory as well as practical application of ideas from Human-Computer Interaction. Coursework includes lectures, class discussion, homework, class presentations, and group projects. This class is open to all undergrads and grad students, with either technical or non-technical majors. However, there is a programming prerequisite. "
Prerequisites: 15-112 or 15-110 or 15-122 or 15-104

Course Website: http://www.hcii.cmu.edu/courses/designing-human-centered-software (http://www.hcii.cmu.edu/courses/designing-human-centered-software/)

05-392 Interaction Design Overview

Fall: 9 units
This studio course offers a broad overview of communication and interaction design. Students will learn design methodologies such as brainstorming, sketching, storyboarding, wire framing, and prototyping. Students learn to take a human-centered design approach to their work. Assignments include short in-class exercises as well as individual and team-based projects. Students take part in studio critiques, engaging in critical discussions about the strengths and weaknesses of their own work and the work of others. No coding is required. When registering for this course, undergraduate students are automatically placed the wait list.

05-395 Applications of Cognitive Science

Spring: 9 units
The goal of this course is to examine cases where basic research on cognitive science, including cognitive neuroscience, has made its way into application, in order to understand how science gets applied more generally. The course focuses on applications that are sufficiently advanced as to have made an impact outside of the research field per se; for example, as a product, a change in practice, or a legal statute. Examples are virtual reality (in vision, hearing, and touch), cognitive tutors, phonologically based reading programs, latent semantic analysis applications to writing assessment, and measures of consumers' implicit attitudes. The course will use a case-study approach that considers a set of applications in detail, while building a general understanding of what it means to move research into the applied setting. The questions to be considered include: What makes a body of theoretically based research applicable? What is the pathway from laboratory to practice? What are the barriers - economic, legal, entrenched belief or practice? The format will emphasize analysis and discussion by students. They should bring to the course an interest in application; extensive prior experience in cognitive science is not necessary. The course will include tutorials on basic topics in cognitive science such as perception, memory, and spatial cognition. These should provide sufficient grounding to discuss the applications.

Course Website: http://www.hcii.cmu.edu/courses/applications-cognitive-science (http://www.hcii.cmu.edu/courses/applications-cognitive-science/)

05-410 User-Centered Research and Evaluation

Fall: 12 units
This course provides an overview and introduction to the field of human-computer interaction (HCI). It introduces students to tools, techniques, and sources of information about HCI and provides a systematic approach to design. The course increases awareness of good and bad design through observation of existing technology and teaches the basic skills of generative and evaluative research methods. This is a companion course to courses in visual design (51-422) and software implementation (05-430, 05-431). When registering for this course, undergraduate students are automatically placed the wait list. Students will be then moved into the class, based on if they are in the BHCI second major and year in school e.g. seniors, juniors, etc. In the Fall, this course is NOT open to students outside the HCI major. The Spring offering is open to all students. This course is a core requirement for students in the HCI additional major.
Prerequisites: 85-421 or 85-408 or 85-370 or 85-251 or 85-213 or 85-211 or 85-241 or 88-120

05-413 Human Factors

Fall: 9 units
This course uses theory and research from human factors, cognitive science, and social science to understand and design the interactions of humans with the built world, tools, and technology. The course emphasizes current work in applied domains such as automotive design, house construction, medical human factors, and design of information devices. The course also will emphasize not only individual human factors (e.g., visual response, anthropometry) but also the organizational arrangements that can amplify or correct human factors problems. Through reading, discussion, and projects, you will learn about human perceptual, cognitive, and physical processes that affect how people interact with, and use, technology and tools. You will learn why we have so many automobile accidents, voting irregularities, and injuries from prescription medication. You will learn some tried and true solutions for human factors problems, and some of the many problems in human factors that remain. You will also have gained experience in research in this field.

Course Website: http://www.hcii.cs.cmu.edu

05-417 Computer-mediated Communication

Spring: 6 units
This course examines fundamental aspects of interpersonal communication and considers how different types of computer-mediated communications (CMC) technologies affect communication processes. Among the topics we will consider are: conversational structure and CMC, tools to support nonverbal and paralinguistic aspects of communication such as gesture and eye gaze, and social and cultural dimensions of CMC. Students will be expected to post to weekly discussion lists, to write a paper on a specific aspect of CMC, and to present a talk on their final project to the class. The course should be appropriate for graduate students in all areas and for advanced undergraduates.

05-418 Design Educational Games

Spring: 12 units
The potential of digital games to improve education is enormous. However, it is a significant challenge to create a game that is both fun and educational. In this course, students will learn to meet this challenge by combining processes and principles from game design and instructional design. Students will also learn to evaluate their games for fun, learning, and the integration of the two. They will be guided by the EDGE framework for the analysis and design educational games. The course will involve a significant hands-on portion, in which students learn a design process to create educational games digital or non-digital. They will also read about existing educational games and discuss game design, instructional design, learning and transfer, and the educational effectiveness of digital games. They will analyze an educational game and present their analysis to the class.

Course Website: https://www.hcii.cmu.edu/course/design-of-educational-games (https://www.hcii.cmu.edu/course/design-of-educational-games/)

05-430 Programming Usable Interfaces

Spring: 15 units
This course is combines lecture, and an intensive programming lab and design studio. It is for those who want to express their interactive ideas in working prototypes. It will cover the importance of human-computer interaction/interface design, iterative design, input/output techniques, how to design and evaluate interfaces, and research topics that will impact user interfaces in the future. In lab, you will learn how to design and program effective graphical user interfaces, and how to perform user tests. We will cover a number of prototyping tools and require prototypes to be constructed in each, ranging from animated mock-ups to fully functional programs. Assignments will require implementing UIs, testing that interface with users, and then modifying the interface based on findings. Some class sessions will feature design reviews of student work. This course is for HCII Masters students and HCI dual majors with a minimal programming background. Students will often not be professional programmers, but will need to interact with programmers. RECITATION SELECTION: Students taking this course can sign up for either Prototyping Lab recitation. PREREQUISITES: Proficiency in a programming language, program structure, algorithm analysis, and data abstraction. Normally met through an introductory programming course using C, C++, Pascal or Java, such as 15100, 15112, 15127 or equivalent. Students entering this course should be able to independently write a 300-line program in 48 hours. This course is NOT open to students outside of the BHCI program.
Prerequisites: 15-110 or 15-104 or 15-112 or 15-127 or 15-100

05-431 Software Structures for User Interfaces

Fall: 12 units
This course considers the basic and detailed concepts for building software to implement user interfaces (UIs). It considers factors of input, output, application interface, and related infrastructure as well as the typical patterns used to implement them. It considers how these aspects are organized and managed within a well-structured object oriented system. We will cover a variety of "front-end" programming contexts, including conventional graphical user interface (GUI) programming for mobile apps (phones, watches), web apps, and regular desktop applications, across a variety of frameworks. We will also cover programming for data-driven and conversational (AI) user interfaces. We will briefly touch on front-end programming for visualizations, games, 3D, and virtual and artificial reality (VR and AR), along with interactive UI tools such as prototypers and resource editors. The homeworks and project in this course will involve extensive object-oriented programming, likely in both Java and JavaScript, so this course is only appropriate for students with a strong programming background. Note that this is not an HCI methods course and #8212; we do not cover user-centered design or evaluation methods. This course is designed for students in the SCS HCI undergrad Major, but it also available to any undergrad or graduate student with an interest in the topic and solid prior programming experience who wish to understand the structures needed for professional development of interactive systems. Note that all students who register for this class will initially be placed on a waitlist. Priority for getting into the class are students in the HCII programs (more senior students first), and then others. The graduate (05-631) and undergraduate (05-431) numbers are for the same course with the same work.
Prerequisites: 17-437 or 17-514 or 17-214 or 15-214 or 15-213 or 18-213 or 15-513 or 14-513

05-432 Personalized Online Learning

Fall: 12 units
Online learning has become widespread (e.g., MOOCs, online and blended courses, and Khan Academy) and many claim it will revolutionize higher education and K-12. How can we make sure online learning is maximally effective? Learners differ along many dimensions and they change over time. Therefore, advanced learning technologies must adapt to learners to provide individualized learning experiences. This course covers a number of proven personalization techniques used in advanced learning technologies. One of the techniques is the use of cognitive modeling to personalize practice of complex cognitive skills in intelligent tutoring systems. This approach, developed at CMU, may well be the most significant application of cognitive science in education and is commercially successful. We will also survey newer techniques, such as personalizing based on student meta-cognition, affect, and motivation. Finally, we will look at personalization approaches that are widely believed to be effective but have not proven to be so. The course involves readings and discussion of different ways of personalizing instruction, with an emphasis on cognitive modeling approaches. Students will learn to use the Cognitive Tutor Authoring Tools (CTAT) to implement tutor prototypes that rely on computer-executable models of human problem solving to personalize instruction. The course is meant for graduate or advanced undergraduate students in Human-Computer Interaction, Psychology, Computer Science, Design, or related fields, who are interested in educational applications. Students should either have some programming skills or experience in the cognitive psychology of human problem solving, or experience with instructional design.

Course Website: http://www.hcii.cmu.edu/courses/personalized-online-learning (http://www.hcii.cmu.edu/courses/personalized-online-learning/)

05-433 Programming Usable Interfaces OR Software Structures for Usable Interfaces

Fall: 6 units
Section A: Programming Usable Interfaces Section B: Software Structures for Usable Interfaces This is a lecture-only course (see 05-430/05-630 or 05-431/631 for the lecture + lab version of these courses) that is intended for those who want to learn how to design and evaluate user interfaces. We will cover the importance of human-computer interaction and interface design, the iterative design cycle used in HCI, an overview of input and output techniques, how to design and evaluate interaction techniques, and end with a discussion of hot topics in research that will impact user interfaces in the coming years. This course is only intended for HCII Masters students or HCI undergraduate majors who have already taken an associated User Interface lab, or non-MHCI/BHCI students interested in the design of user interfaces. WAITLIST LOGISTICS: Note that ALL students who register for this class will initially be placed on a waitlist. Your position on the waitlist is not an indication of whether you will be accepted into the class. Contacting the instructor will not move you off the waitlist. Priority for getting off the waitlist are MHCI students, BHCI students (more senior students first), and then others.

05-434 Machine Learning in Practice

Fall and Spring: 12 units
Machine Learning is concerned with computer programs that enable the behavior of a computer to be learned from examples or experience rather than dictated through rules written by hand. It has practical value in many application areas of computer science such as on-line communities and digital libraries. This class is meant to teach the practical side of machine learning for applications, such as mining newsgroup data or building adaptive user interfaces. The emphasis will be on learning the process of applying machine learning effectively to a variety of problems rather than emphasizing an understanding of the theory behind what makes machine learning work. This course does not assume any prior exposure to machine learning theory or practice. In the first 2/3 of the course, we will cover a wide range of learning algorithms that can be applied to a variety of problems. In particular, we will cover topics such as decision trees, rule based classification, support vector machines, Bayesian networks, and clustering. In the final third of the class, we will go into more depth on one application area, namely the application of machine learning to problems involving text processing, such as information retrieval or text categorization. 05-834 is the HCII graduate section. If you are an LTI student, please sign up for the LTI graduate course number (11-663) ONLY to count properly towards your degree requirements. 05-434 is the HCII undergraduate section. If you are an LTI student, please sign up for the LTI undergraduate course number (11-344) ONLY to count properly towards your degree requirements.

Course Website: http://www.hcii.cmu.edu/courses/applied-machine-learning (http://www.hcii.cmu.edu/courses/applied-machine-learning/)

05-435 Applied Fabrication for HCI

Fall: 12 units
This course will consider how new fabrication techniques such as 3D printing, laser cutting, CNC machining and related computer controlled technologies can be applied to problems in Human-Computer Interaction. Each offering will concentrate on a particular application domain for its projects. This year the course will consider assistive technology. This course will be very hands-on and skills-oriented, with the goal of teaching students the skills necessary to apply these technologies to HCI problems such as rapid prototyping of new device concepts. To this end? Every student in this course will build and take home a 3D printer. (There will be $400-$500 cost associated with this course to make that possible. Details on this are still to be determined.)

05-436 Usable Privacy and Security

Spring: 9 units
There is growing recognition that technology alone will not provide all of the solutions to security and privacy problems. Human factors play an important role in these areas, and it is important for security and privacy experts to have an understanding of how people will interact with the systems they develop. This course is designed to introduce students to a variety of usability and user interface problems related to privacy and security and to give them experience in designing studies aimed at helping to evaluate usability issues in security and privacy systems. The course is suitable both for students interested in privacy and security who would like to learn more about usability, as well as for students interested in usability who would like to learn more about security and privacy. Much of the course will be taught in a graduate seminar style in which all students will be expected to do a weekly reading assignment and each week different students will prepare a presentation for the class. Students will also work on a group project throughout the semester. The course is open to all graduate students who have technical backgrounds. The 12-unit course numbers (08-734 and 5-836) are for PhD students and masters students. Students enrolled in these course numbers will be expected to play a leadership role in a group project that produces a paper suitable for publication. The 9-unit 500-level course numbers (08-534 and 05-436) are for juniors, seniors, and masters students. Students enrolled in these course numbers will have less demanding project and presentation requirements.

Course Website: http://www.hcii.cmu.edu/courses/usuable-privacy-and-security (http://www.hcii.cmu.edu/courses/usuable-privacy-and-security/)

05-439 The Big Data Pipeline: Collecting and Using Big Data for Interactive Systems

Spring: 12 units
This course covers techniques and technologies for creating data driven interfaces. You will learn about the entire data pipeline from sensing to cleaning data to different forms of analysis and computation.

Course Website: http://data.cmubi.org

05-440 Interaction Techniques

Intermittent: 12 units
This course will provide a comprehensive study of the many ways to interact with computers and computerized devices. An "interaction technique" starts when the user does something that causes an electronic device to respond and includes the direct feedback from the device to the user. Examples include physical buttons and switches, on-screen menus and scroll bars operated by a mouse, touch screen widgets and gestures such as flick-to-scroll, text entry on computers or touch screens, game controllers, interactions in 3D and virtual/augmented reality, consumer electronic controls such as remote controls, and adaptations of all of these for people with disabilities. We will start with a history of the invention and development of these techniques, discuss the various options used today, and continue on to the future with the latest research on interaction techniques presented at conferences such as ACM CHI and UIST. Appropriate design and evaluation methods for interaction techniques will also be covered. Guest lectures from inventors of interaction techniques are planned. Students will have a choice for final projects that can focus on historical or novel interaction techniques.

Course Website: http://www.cs.cmu.edu/~bam/uicourse/05440inter/

05-452 Service Design

Fall: 12 units
In this course, we will collectively define and study services and product service systems, and learn the basics of designing them. We will do this through lectures, studio projects, and verbal and written exposition. Classwork will be done individually and in teams.

05-470 Digital Service Innovation

Intermittent: 12 units
Attention entrepreneurs, designers, and engineers! This course teaches you to invent digital services. You will learn about value-creation in the service sector and a human-centered design process including brainstorming, story-boarding, interviewing, video sketches, and pitching. Students work in small, interdisciplinary teams to discover unmet needs of users. They conceive of a digital service and assess its technical feasibility, financial viability, and desirability. Then they produce a plan with a business model and a video sketch and pitch it to industry professionals. Grades will be determined primarily by the quality of the team's products.

Course Website: https://www.hcii.cmu.edu/course/digital-service-innovation (https://www.hcii.cmu.edu/course/digital-service-innovation/)

05-499 Special Topics in HCI

Fall and Spring: 12 units
Special Topics in HCI is an opportunity for students interested in HCI to gain a deeper understanding of a specific area in this field. Each class is designed to cover an emerging research area within HCI, from designing large-scale peer learning systems to designing games around audience agency. All sections will help students: (1) build a more comprehensive understanding of an area of study within HCI, (2) work closely with faculty and peers to create mini-projects or team assignments that help students master the course material, (3) explore evidence-based research methods and techniques in HCI. Sections will vary in topic and often change from semester to semester. Because of this, students can take multiple sections, as they are individual classes. Undergraduate sections are listed as 499 and graduate sections are listed as 899. For descriptions of specific sections for this academic year, visit the "Courses" section on the Human-Computer Interaction Institute website.

Course Website: http://www.hcii.cmu.edu/academics/courses (http://www.hcii.cmu.edu/academics/courses/)

05-540 Rapid Prototyping of Computer Systems

Spring: 12 units
This is a project-oriented course, which will deal with all four aspects of project development: the application, the artifact, the computer-aided design environment, and the physical prototyping facilities. The class consists of students from different disciplines who must synthesize and implement a system in a short period of time. Upon completion of this course the student will be able to: generate systems specifications from a perceived need; partition functionality between hardware and software; produce interface specifications for a system composed of numerous subsystems; use computer-aided development tools; fabricate, integrate, and debug a hardware/software system; and evaluate the system in the context of an end user application. The class consists of students from different disciplines who must synthesize and implement a system in a short period of time.

Course Website: http://www.hcii.cmu.edu/courses/rapid-prototyping-computer-systems (http://www.hcii.cmu.edu/courses/rapid-prototyping-computer-systems/)

05-571 Undergraduate Project in HCI

Spring: 12 units
Experiential learning is a key component of the MHCI program. Through a substantial team project, students apply classroom knowledge in analysis and evaluation, implementation and design, and develop skills working in multidisciplinary teams. Student teams work with Carnegie Mellon University-based clients or external clients to iteratively design, build and test a software application which people directly use.
Prerequisites: 05-631 Min. grade B or 05-410 Min. grade B or 05-430 Min. grade B or 05-431 Min. grade B or 05-610 Min. grade B or 05-630 Min. grade B

Course Website: http://www.hcii.cmu.edu/courses/undergraduate-project-hci (http://www.hcii.cmu.edu/courses/undergraduate-project-hci/)

05-589 Independent Study in HCI-UG

All Semesters
In collaboration with and with the permission of the professor, undergraduate students may engage in independent project work on any number of research projects sponsored by faculty. Students must complete an Independent Study Proposal, negotiate the number of units to be earned, complete a contract, and present a tangible deliverable. The Undergraduate Program Advisor's signature is required for HCI undergraduate-level Independent Study courses. Registration is through the HCII Undergraduate Programs Manager only.

05-600 HCI Pro Seminar

Fall: 6 units
This course is only for MHCI students. This course is specifically built to expose students to the world of HCI through research and industry talks, as well as strengthening HCI communication skills for work in industry. Seminar Component:To expose students to the world of HCI through research and industry expert talks with written assignments. Conflict Management Component:To educate students on conflict management, teamwork, active listening skills, and communication skills in order to give them tools to collaborate and work more efficiently on multi-disciplinary teams. Professional Series Component: To expose students to the world of HCI through guest speakers, prepare students to navigate job hunting through resume and portfolio workshops and to provide industry insights into HCI and the profession through guest speakers and panel discussions.

Course Website: http://www.hcii.cs.cmu.edu

05-602 IDeATe: Learning in Museums

Spring: 12 units
Learning in Museums brings together students from across the disciplines to consider the design of mediated learning experiences in a project-based inquiry course. Students will be introduced to a range of design research methods and associated frameworks that explore the cognitive, social and affective dimensions of learning in everyday contexts through readings, invited lectures, in-class activities and assignments. Students will conduct a series of short design research studies to define learning goals and develop supporting design concepts intended to improve learning outcomes for diverse participants in informal learning settings (e.g. museums, after-school programs, maker spaces or online). In concept development, we will look at how to position technology and question its role in the setting to engage and foster positive learning interactions and conversation. This semester we will be working with the Carnegie Museum of Natural History as our primary stakeholder. The course will culminate in a media-rich presentation of design concepts and a fielded prototype to a review panel and include a piloted evaluation plan describing how learning outcomes for the project would be assessed. In consultation with the instructor, students in the graduate section of the course will be assigned an HCI/learning research literature review and presentation related to their project topic.

05-610 User-Centered Research and Evaluation

Fall: 12 units
This course provides and overview and introduction to the field of human-computer interaction (HCI). It introduces students to tools, techniques, and sources of information about HCI and provides a systematic approach to design. The course increases awareness of good and bad design through observation of existing technology, and teaches the basic skills of generative and evaluative research methods. This is a companion course to software implementation (05-430, 05-431 05-380). When registering for this course, undergraduate students are automatically placed the wait list. Students will be then moved into the class, based on if they are in the BHCI primary or second major and year in school e.g. seniors, juniors, etc. Freshman are not permitted to register in this course. In the Fall, this course is NOT open to students outside the HCI major or MHCI. The Spring offering is open to all students. This course is a core requirement for students in the HCI additional major and the MHCI program.
Prerequisites: 85-213 or 85-211 or 85-241 or 88-120 or 85-370 or 85-408 or 85-421 or 85-251

Course Website: http://www.hcii.cs.cmu.edu

05-615 Persuasive Design

Fall: 12 units
This project-based course focuses on the ethical, human-centered design and evaluation of persuasive technologies that aim to change users' attitudes, emotions, or behaviors in ways that benefit the self and/or society. In addition to exposing students to an array of psychological theories and strategies for implicit and explicit persuasion, the course will cover a variety of topics illustrating both the pitfalls and possibilities in designing for positive impact in HCI. The focal point of the class will be the semester project, for which student teams will iteratively conceptualize, prototype, implement, and evaluate a tool, system, or change to a ubiquitous computing environment that intends to stimulate and sustain belief or behavior change (such as reducing cognitive or social biases, building healthy or prosocial habits, or resisting other persuasive forces one encounters on a daily basis).

05-618 Human AI Interaction

Intermittent: 12 units
Artificial Intelligence is inspired by human intelligence, made powerful by human data, and ultimately only useful in how it positively affects the human experience. This course is an introduction to harnessing the power of AI so that it is beneficial and useful to people. We will cover a number of general topics: agency and initiative, AI and ethics, bias and transparency, confidence and errors, human augmentation and amplification, trust and explainability, mixed-initiative systems, and programming by example. These topics will be explored via projects in dialog and speech-controlled systems, automatic speech recognition, computer vision, data science, recommender systems, text summarization, learning science, UI personalization, and visualization. Students will complete individual weekly mini-projects in which they will design and build AI systems across a wide variety of domains. Students should be comfortable with programming; assignments will be primarily in Python and Javascript. Prior experience with AI/machine learning will be useful but is not required. Students will also be responsible for weekly readings and occasional presentations to the class.

Course Website: https://www.hcii.cmu.edu/academics/courses (https://www.hcii.cmu.edu/academics/courses/)

05-619 Data Visualization

Fall: 12 units
This course is an introduction to key design principles and techniques for interactively visualizing data. The major goals of this course are to understand how visual representations can help in the analysis and understanding of complex data, how to design effective visualizations, and how to create your own interactive visualizations using modern web-based frameworks.

Course Website: https://dig.cmu.edu/courses/2022-fall-datavis.html

05-650 Interaction Design Studio II

Spring: 12 units
This course follows Interaction Design Fundamentals (05-651). Students are expected to apply what they have learned about design thinking and methodologies as a starting point for all assignments. Students will work in teams to perform guerrilla research, synthesize data, and consider the needs of multiple stakeholders in their design of mobile services and other intelligent systems. Design concepts go beyond user interfaces to include sensors, controls, and ubiquitous computing. Emphasis is placed on the quality of the students ideas and their ability to give form to their design concepts. By completing and presenting their work, students will gain skills related to professional UX design practice.
Prerequisite: 05-651

Course Website: http://www.hcii.cmu.edu/courses/interaction-design-studio (http://www.hcii.cmu.edu/courses/interaction-design-studio/)

05-651 Interaction Design Studio 1

Fall: 12 units
This studio course introduces students to design thinking and the basic practices of interaction design. We follow a human-centered design process that includes research, concept generation, prototyping, and refinement. Students must work effectively as individuals and in small teams to design mobile information systems and other interactive experiences. Assignments approach design on three levels: specific user interactions, contexts of use, and larger systems. Students will become familiar with design methodologies such as sketching, storyboarding, wire framing, prototyping, etc. No coding is required. This course serves as a prerequisite for Interaction Design Studio (05-650). Students who are required to take this course have priority and will be enrolled first.

05-660 Interaction Design Fundamentals

Fall and Spring: 12 units
IXD Fundamentals introduces the human-centered design process as well as fundamental interaction design principles, methods, and practices. The course is for both students who may only enroll in one interaction design course and those who intend to build upon their HCI learning by taking advanced interaction design courses. Students must work effectively as individuals and in small teams to learn interaction design concepts and apply them to real-world problems. By the end of this course students should be able to; -Apply appropriate interaction design methods in a human-centered design process. -Create persuasive interim and final design artifacts that demonstrate communication design fundamentals. -Facilitate productive and structured critique across the class and with instructors. -Explain and apply fundamental interaction design principles. -Create clarity and readability in artifacts, including GUIs and deliverables, through the disciplined application of visual design principles such as typography, color and composition. -Practice reframing a given problem in order to create opportunities that drive generating multiple solutions. -Demonstrate habits that foster the creative process, including drawing, divergent thinking, and creative experimentation. -Identify and explore with interaction design materials. This course serves as a prerequisite for Advanced Interaction Design Studio (number TBD). Students who are required to take this course have priority and will be enrolled first. No coding is required.

05-661 Advanced Interaction Design

Spring: 12 units
Advanced Interaction Design (05-361/05-661) follows Interaction Design for Human-Computer Interaction (05-360/05-660). Students are expected to build on the basic interaction design principles they learned in Interaction Design Fundamentals by applying advanced methods to solve more complex problems using emerging technologies in user experiences that cross devices, modalities and contexts. Students learn how to design with advanced technologies that predict, assist and automate, and make through a design system. Systems thinking, data as a design material, and UI design are emphasized in projects which are designed to give students experience solving complex problems that they are likely to encounter as practitioners. Advanced Interaction Design prepares students to become interaction designers that take a rigorous and principled approach to solving enterprise-scale problems where many systems and applications serve many stakeholders.
Prerequisites: 05-651 or 05-692 or 05-660

05-670 Digital Service Innovation

Fall: 12 units
Attention entrepreneurs, designers, and engineers! This course teaches you to invent digital services. You will learn about value-creation in the service sector and a human-centered design process including brainstorming, story-boarding, interviewing, video sketches, and pitching. Students work in small, interdisciplinary teams to discover unmet needs of users. They conceive of a digital service and assess its technical feasibility, financial viability, and desirability. Then they produce a plan with a business model and a video sketch and pitch it to industry professionals. Grades will be determined primarily by the quality of the team's products.

Course Website: https://www.hcii.cmu.edu/course/digital-service-innovation (https://www.hcii.cmu.edu/course/digital-service-innovation/)

05-674 Ethics and Policy Issues in Computing

Intermittent: 9 units
Should autonomous robots make life and death decisions on their own? Should we allow them to select a target and launch weapons? To diagnose injuries and perform surgery when human doctors are not around? Who should be permitted to observe you, find out who your friends are, what you do and say with them, what you buy, and where you go? Do social media and personalized search restrict our intellectual horizons? Do we live in polarizing information bubbles, just hearing echoes of what we already know and believe? As computing technology becomes ever more pervasive and sophisticated, we are presented with an escalating barrage of decisions about who, how, when, and for what purposes technology should be used. This course will provide an intellectual framework for discussing these pressing issues of our time, as we shape the technologies that in turn shape us. We will seek insight through reading, discussion, guest lectures, and debates. Students will also undertake an analysis of a relevant issue of their choice, developing their own position, and acquiring the research skills needed to lend depth to their thinking. The course will enhance students' ability to think clearly about contentious technology choices, formulate smart positions, and support their views with winning arguments.

05-680 Independent Study in HCI - METALS

All Semesters
With the permission of the professor, METALS students may engage in independent project work on any number of innovative research projects sponsored by faculty. Students must complete an Independent Study Proposal, negotiate the number of units to be earned, submit a contract, and present a tangible deliverable. The Program Advisor's signature is required for the METALS Independent Study course.

05-685 Prototyping Algorithmic Experiences

Intermittent: 15 units
This project-based, technical studio course provides an overview and hands-on introduction to iterative prototyping methods in HCI. Students learn methods and strategies to iteratively prototype novel technologies with users. Students will practice strategically evaluating whether a given prototyping approach is a good fit for a given design or research question (e.g., in terms of expected time, effort, and informativeness). Through a series of rapid course projects, students will explore the cutting-edge of HCI methods for prototyping complex interactive experiences with challenging design materials, such as AI and machine learning, social computing, and spatial computing. In addition to HCI undergraduate majors, the course is open to undergraduate and graduate level students with proficiency in programming and prior courses or experience in user-centered research, design, and/or evaluation. Some exceptions to the course prerequisites will be granted with permission of the instructor.
Prerequisites: 15-112 and (15-210 or 15-150 or 15-122 or 15-121) and (05-891 or 05-651 or 05-650 or 05-652 or 05-610 or 05-617 or 05-660 or 05-392 or 05-670)

05-738 Evidence-Based Educational Design

Fall: 12 units
In this course, we will explore the essential principles of educational design, focusing on creating inclusive environments for diverse learners and promoting positive behavior. We will explore effective strategies for measuring learning outcomes, enhancing student engagement, and assessing educational effectiveness. Students will prepare for careers as instructional designers, learning engineers, educators, and researchers as we cover the range of topics in this class. The coursework includes a thorough examination of current research in learning sciences through various papers and textbooks. Additionally, students will apply these theoretical principles practically by completing two hands-on projects, seeing the direct application of the concepts to real-world use cases. Class time will be spent discussing the weekly readings, highlighting relevant case studies, and engaging in group activities that foster collaboration and practical application of the material covered. This course will prepare students for real-world challenges in educational design and help integrate learning science knowledge through practical experience, enabling them to create effective educational designs and strategies.

05-823 E-Learning Design Principles and Methods

Fall: 12 units
Good design is a continuous improvement process that combines scientific principles and data-driven methods to achieve desired outcomes. E-learning design is no exception. In this course, you will learn how to design innovative e-learning, that is, online interactions and technology that make learning more effective and efficient. You will practice instructional design using learning science theories and principles and learning engineering using data-driven methods to discover insights about how learners think. Instructional designers explain and use principles of learning and instruction such as proven ways to support learning-by-doing, like deliberate practice and self-explanation, and proven ways to support multimedia learning from text, visuals, and audio. They employ "backward design": designing and aligning learning goals, the assessments that measure them, and the instruction that achieves them. But today's learning engineers do not simply design in sequence and #8212; goals then assessments then instruction and #8212; but are agile and iterative. They collect qualitative data, for example, by having an expert "think aloud" while performing one of their assessments and use the results to add or change goals. They collect and use quantitative data, for example, by mining learning data from online course interactions or by comparing alternative designs in an A/B experiment. By using data, learning engineers create innovative and effective designs unlike the results of others who rely on science and intuition alone. You will do so too in an end-to-end e-learning design project, where you develop an e-learning module of your choice, continuously improve it, and test it in an A/B experiment.

Course Website: https://www.hcii.cmu.edu/course/e-learning-design-principles (https://www.hcii.cmu.edu/course/e-learning-design-principles/)

05-839 Interactive Data Science

Spring: 12 units
This course covers techniques and technologies for creating data driven interfaces. You will learn about the entire data pipeline from sensing to cleaning data to different forms of analysis and computation.

Course Website: https://hcii.cmu.edu/academics/courses (https://hcii.cmu.edu/academics/courses/)

05-840 Tools for Online Learning

Fall: 12 units
In this course, we will explore issues that pertain to interaction and interface design. The class will focus on elements of the larger interaction design process including basic design principles, information architecture and navigation, planning and brainstorming methods, and techniques for developing rapid sketches and prototypes. Course Requirements: This class will not focus on learning specific software tools. Students are expected to have prior experience using a variety of design and programming tools. Please speak with the instructor if you have questions regarding these prerequisites. This course was design for students in the METALS program.

Software Societal Systems Courses

08-200 Ethics and Policy Issues in Computing

Spring: 9 units
In this course, students will study the social impacts of computing technology and systems. The course will provide a brief introduction to ethics and to the new and difficult ethical questions modern computing technology presents us with. It will focus on a number of areas in which computers and information technology are having an impact on society including data privacy, social media, and autonomous technologies.

08-722 Data Structures for Application Programmers

Fall and Spring: 6 units
This course is an introduction to Data Structures and a few fundamental algorithms for students with some prior programming experience (functions, loops and arrays mainly in Java). It covers the conceptual and implementation views of some common data structures and algorithms. It also goes over the Java Collections (such as List, ArrayList, LinkedList, Set, HashSet, TreeSet, Map, HashMap, TreeMap, PriorityQueue) to solidify the understanding of the data structures. There is an introduction to the analysis of algorithms that operate on them. Following learning-by-doing methodology, there will be many repetitions of writing code and reviews of the items covered in lectures. Students are required to be familiar with Java Programming before taking this course. Those who are not are encouraged to take 08-671 in mini 1 before taking this course. Students are required to have a reasonably modern laptop computer on which install the Java software used for this course.

Language Technologies Institute Courses

11-291 Applied Computational Intelligence Lab

Intermittent: 9 units
What would an "intelligent" picture on the wall do? What if it could see and hear you? What should it say if it could talk? What if your pantry, wardrobe or medicine cabinet could sense, think and act? What should they do and say? What should your cell phone be saying to you? These are not whimsical or theoretical questions...they inevitably arise as ordinary everyday objects around us acquire the ability to sense changes in their environment, think about their implications, and act in pursuit of their goals. These objects are connected to the web and become conduits for services, erasing the distinction between products and services. The ability to invent and build smart products/services is becoming a key skill in the new technology-driven services economy. The focus of the course will be on building "ordinary" objects that can sense, think and act in the real world and on exploring the implications of these capabilities. Students will select their own project and by the end of the semester will create a working prototype that will be exhibited in a public place. Prizes will be offered for the most creative projects. In the course of their projects, students will learn how to use state-of-the-art tools for: Object detection using video cameras, microphones and other sensors Movement and gesture detection Speech recognition and generation Reasoning and planning: While the course organizers have many ideas for specific projects, students will be encouraged to design their own projects. Students are expected to work in small groups on their own time and receive faculty advice as needed. There will be weekly meetings of the whole class.
Prerequisites: 21-127 Min. grade C and 15-122 Min. grade C

11-324 Human Language for Artificial Intelligence

Fall: 12 units
An enduring aspect of the quest to build intelligent machines is the challenge of human language. This course introduces students with a background in computer science and a research interest in artificial intelligence fields to the structure of natural language, from sound to society. It covers phonetics (the physical aspects of speech), phonology (the sound-structure of language), morphology (the structure of words), morphosyntax (the use of word and phrase structure to encode meaning), syntactic formalisms (using finite sets of production rules to characterize infinite configurations of structure), discourse analysis and pragmatics (language in discourse and communicative context), and sociolinguistics (language in social context and social meaning). Evaluation is based on seven homework assignments, a midterm examination, and a final examination.

11-344 Machine Learning in Practice

Fall and Spring: 12 units
Machine Learning is concerned with computer programs that enable the behavior of a computer to be learned from examples or experience rather than dictated through rules written by hand. It has practical value in many application areas of computer science such as on-line communities and digital libraries. This class is meant to teach the practical side of machine learning for applications, such as mining newsgroup data or building adaptive user interfaces. The emphasis will be on learning the process of applying machine learning effectively to a variety of problems rather than emphasizing an understanding of the theory behind what makes machine learning work. This course does not assume any prior exposure to machine learning theory or practice. In the first 2/3 of the course, we will cover a wide range of learning algorithms that can be applied to a variety of problems. In particular, we will cover topics such as decision trees, rule based classification, support vector machines, Bayesian networks, and clustering. In the final third of the class, we will go into more depth on one application area, namely the application of machine learning to problems involving text processing, such as information retrieval or text categorization.

11-345 Undergrad Independent Study

All Semesters
No course description provided.

11-364 An Introduction to Knowledge-Based Deep Learning and Socratic Coaches

Spring: 12 units
The subject of this course will be deep learning, one of the most dynamic and exciting emerging areas of computer science. Deep learning deals with and is conquering the problems resulting from the enormous quantity of data that now surrounds us. Furthermore, the course will explore knowledge-based deep learning, a new methodology invented by the instructor that offers many potential advantages over conventional deep learning. This is a learn-by-doing, team-project based course, which will be divided into four phases. In phase one, each student will read and present a number of papers describing state-of-the-art deep learning systems and successful applications. In phase two, each team will implement the system described in one of the papers. In phase three, each team will scale that implementation to one of the large benchmark datasets. In phase four, each team will do a special research project implementing a knowledge-based deep learning system based on pending patent applications of Professor Baker. As a potential follow-on for successful projects, students may participate in a summer course on entrepreneurial applications of deep learning or work as interns in a bootstrap startup based on the knowledge-based deep learning projects. Prerequisite: Strong quantitative aptitude, programming skill, ability to quickly absorb new ideas, teamwork skills.

11-390 LTI Minor Project - Juniors

All Semesters: 12 units
No course description provided.

11-411 Natural Language Processing

Intermittent: 12 units
This course is about a variety of ways to represent human languages (like English and Chinese) as computational systems, and how to exploit those representations to write programs that do neat stuff with text and speech data, like translation, summarization, extracting information, question answering, natural interfaces to databases, and conversational agents. This field is called Natural Language Processing or Computational Linguistics, and it is extremely multidisciplinary. This course will therefore include some ideas central to Machine Learning and to Linguistics. We'll cover computational treatments of words, sounds, sentences, meanings, and conversations. We'll see how probabilities and real-world text data can help. We'll see how different levels interact in state-of-the-art approaches to applications like translation and information extraction. From a software engineering perspective, there will be an emphasis on rapid prototyping, a useful skill in many other areas of Computer Science.
Prerequisite: 15-122

11-422 Grammar Formalisims

Spring: 12 units
TBA

11-423 ConLanging: Lrng. Ling. & Lang Tech via Constru Artif. Lang.

Spring: 12 units
Students will work individually or in small groups to create artificial human(oid) languages for fictional human cultures or SciFi worlds. Students will implement language technologies for their languages. In the course of creating the languages, students will learn about the building blocks of human language such as phones, phonemes, morphemes, and morpho-syntactic constructions including their semantics and pragmatics. Class instruction will focus specifically on variation among human languages so that the students can make conlangs that are not just naively English-like. We will also touch on philosophical issues in philosophy of language and on real-world socio-political issues related to language policy. Students will be required to use at least one of the following technologies: language documentation tools that are used for field linguistics and corpus annotation, automatic speech recognition, speech synthesis, morphological analysis, parsing, or machine translation. Learning Objectives: 1. The building blocks (phonemes, morphemes, etc.) of language, how languages are built from them, and how they interact 2. Metalinguistic awareness and knowledge about variation in human language 3. Language, thought, and culture: how does language reflect thought and culture, and vice versa. Why wouldn't Elvish be a good language for Klingons? 4. Language policy in the real world: For students who want to manipulate real languages. 5. Historical linguistics and language change: for students who want to manipulate real languages or make families of related conlangs for fictional worlds. 6. Practical experience with a language technology. http://tts.speech.cs.cmu.edu/11-823/
Course Website: http://tts.speech.cs.cmu.edu/11-823 (http://tts.speech.cs.cmu.edu/11-823/)

11-424 Subword Modeling

Intermittent: 12 units
The goal of this course is to lead students to engage broadly with the existing NLP and computational linguistics research on subword modeling and develop new computational approaches to problems in morphology, orthography, and phonology. In addition to three other miniprojects, students will be expected to produce one piece of research that can be developed into a conference or workshop paper (though submission is not a course requirement). The paper should be suitable for the Phonology, Morphology, and Word Segmentation tracks of the *ACL conferences, the SIGMORPHON workshop, Coling, or LREC.
Prerequisites: 11-611 or 11-711 or 11-411

11-439 Designing Around Patents on Machine Learning and NLP Technology

Spring: 9 units
This course uses Machine Learning and Natural Language Processing as vehicles to teach principles in designing software to avoid patents. After introducing students to the basics of patents, we investigate how to use students software skills to design around patents that is, create new technology that avoids a patent while maintaining some, or even all, of the performance and value of the patented technology. Designing around a patent can be viewed as a puzzle that requires technical skill, understanding the business value of technology, knowledge of patents, and creativity. Students will also be able to help design patents that cannot be easily designed-around. Not only does this add a valuable new dimension to the student's skill set, the course material is organized as a vehicle for refining knowledge of ML and NLP techniques. We will practice by designing around patents on well-known ML and NLP algorithms. Students study the basic algorithm, learn the patents that cover those algorithms, and then experiment with software modifications that avoid the patent while preserving as much of the algorithm's performance as possible. In essence, students will view the presence of particular patents as a design constraints, akin to designing for limited memory, bandwidth, or processor speed. Students must have already taken courses in Natural Language Processing (e.g., 11-411) and Machine Learning (e.g., 10-315). Law of Computer Technology 17-562, 17-662, 17-762 or Patents, Licensing, and Innovation 19-473, 19-673 are helpful but not required.

11-441 Machine Learning with Graphs

Fall and Spring: 9 units
Graphs offer a natural way to represent complex relationships among objects of all kinds. Neural network learning with graphs has become important in both academic research and industrial applications. This course (for graduate and undergraduate students who meet the prerequisites) offers a mixture of fundamental concepts, algorithms, basic and advanced models, and broad applications, ranging from social popularity analysis and knowledge graph reasoning to deep learning for solving NP-complete problems.
Prerequisites: 15-213 and (21-241 or 21-341) and 21-325 and (10-701 or 10-601)

Course Website: https://cmu-ml4graph.github.io/s2024/

11-442 Search Engines

Fall: 9 units
This course studies the theory, design, and implementation of text-based search engines. The core components include statistical characteristics of text, representation of information needs and documents, several important retrieval models, and experimental evaluation. The course also covers common elements of commercial search engines, for example, integration of diverse search engines into a single search service ("federated search", "vertical search"), personalized search results, diverse search results, and sponsored search. The software architecture components include design and implementation of large-scale, distributed search engines.
Prerequisites: (36-225 or 15-259 or 21-325 or 36-218) and 15-210 Min. grade C and 15-213 Min. grade C and 21-241

Course Website: http://boston.lti.cs.cmu.edu/classes/11-642/

11-485 Introduction to Deep Learning

Intermittent: 9 units
Neural networks have increasingly taken over various AI tasks, and currently produce the state of the art in many AI tasks ranging from computer vision and planning for self-driving cars to playing computer games. Basic knowledge of NNs, known currently in the popular literature as "deep learning", familiarity with various formalisms, and knowledge of tools, is now an essential requirement for any researcher or developer in most AI and NLP fields. This course is a broad introduction to the field of neural networks and their "deep" learning formalisms. The course traces some of the development of neural network theory and design through time, leading quickly to a discussion of various network formalisms, including simple feedforward, convolutional, recurrent, and probabilistic formalisms, the rationale behind their development, and challenges behind learning such networks and various proposed solutions. We subsequently cover various extensions and models that enable their application to various tasks such as computer vision, speech recognition, machine translation and playing games. Instruction Unlike prior editions of 11-785, the instruction will primarily be through instructor lectures, and the occasional guest lecture. Evaluation Students will be evaluated based on weekly continuous-evaluation tests, and their performance in assignments and a final course project. There will be six hands-on assignments, requiring both low-level coding and toolkit-based implementation of neural networks, covering basic MLP, convolutional and recurrent formalisms, as well as one or more advanced tasks, in addition to the final project.
Prerequisites: 15-112 and 21-120 and 21-241

11-488 Concepts in Digital Multimedia and Cyber Forensics

Spring: 12 units
This course covers the use of computational methods in crime investigation (forensics) and prevention (intelligence). In almost all areas of forensics and intelligence, computational methods continue to aid, and sometimes entirely replace, human expertise in tracking crime. This is desirable since automation can address the problems associated with scale and global crime linkage through diverse data computational tools can potentially overcome and surpass human capabilities for crime investigation. This course is of a cross-disciplinary nature. It amalgamates knowledge from criminology, forensic sciences, computer science, statistics, signal processing, machine learning, AI, psychology, medicine and many other fields. Students from all departments and schools are welcome to take this course.

Course Website: https://forensics-ai.github.io/gh-syllabus/

11-490 LTI Minor Project - Seniors

All Semesters: 12 units
No course description provided.

11-492 Speech Technology for Conversational AI

Spring: 12 units
This course provides both practical and theoretical knowledge on how we can leverage speech processing technologies to build a conversational AI system. The course encompasses speech recognition, speaker recognition, speech synthesis, speech enhancement, speech translation, spoken dialogue systems, speech foundation models, and other speech and audio processing tasks. In practical sessions, students will learn to build functional speech recognition and synthesis systems or utilize existing large speech and language models and integrate them to create a speech interface using existing toolkits. The course will also present details of algorithms, techniques, evaluation metrics, and limitations of state-of-the-art speech systems. This course is particularly designed for students who want to learn how to process actual data for real-world applications, applying AI and machine learning techniques while also being aware of the current technology limitations.
Prerequisite: 15-210

11-546 Applied Legal Analytics & Artificial Intelligence

Spring: 12 units
Technological advances are affecting the legal profession and enable innovation by experts proficient in both law and AI technology. This joint course, co-taught by instructors from the University of Pittsburgh School of Law and Carnegie Mellon Universitys Language Technologies Institute, provides a hands-on practical introduction to the fields of artificial intelligence and law, machine learning, and natural language processing as they are being applied to support the work of legal professionals, researchers, and administrators, such as extracting semantic information from legal documents and using it to solve legal problems. Meanwhile, LegalTech companies and startups have been tapping into the industrys need to make large-scale document analysis tasks more efficient, and to use predictive analytics for better decision making. This course is intended to bring students of law and technical disciplines together into a collaborative classroom setting to learn about the technologies at the intersection of law and AI through lectures and programming exercises, as well as gain practical experience through collaborative project work. Topics in focus include machine learning and natural language applied to legal data, computational models of legal reasoning, and selected legal issues that relate to AI technologies. Students should come from either a (pre-) law background with a strong interest in gaining practical experience with legal analytics, or from a technical discipline with a equally strong interest in tackling the challenges posed by legal analytics tasks and data.

Course Website: https://luimagroup.github.io/appliedlegalanalytics/

11-590 LTI Minor Project - Advanced

All Semesters: 12 units
No course description provided.

11-603 Python for Data Science

Summer: 12 units
Students learn the concepts, techniques, skills, and tools needed for developing programs in Python. Core topics include types, variables, functions, iteration, conditionals, data structures, classes, objects, modules, and I/O operations. Students get an introductory experience with several development environments, including Jupyter Notebook, as well as selected software development practices, such as test-driven development, debugging, and style. Course projects include real-life applications on enterprise data and document manipulation, web scraping, and data analysis.

Course Website: https://canvas.andrew.cmu.edu

11-624 Human Language for Artificial Intelligence

Fall: 12 units
An enduring aspect of the quest to build intelligent machines is the challenge of human language. This course introduces students with a background in computer science and a research interest in artificial intelligence fields to the structure of natural language, from sound to society. It covers phonetics (the physical aspects of speech), phonology (the sound-structure of language), morphology (the structure of words), morphosyntax (the use of word and phrase structure to encode meaning), syntactic formalisms (using finite sets of production rules to characterize infinite configurations of structure), discourse analysis and pragmatics (language in discourse and communicative context), and sociolinguistics (language in social context and social meaning). Evaluation is based on seven homework assignments, a midterm examination, and a final examination.

11-630 MCDS Practicum Internship

Summer
The MCDS Practicum course is used for recording CDS students summer internships for the MCDS Program.

11-639 Designining Around Patents on Machine Learning and NLP Technology

Spring: 12 units
This course uses Machine Learning and Natural Language Processing as vehicles to teach principles in designing software to avoid patents. After introducing students to the basics of patents, we investigate how to use students software skills to design around patents that is, create new technology that avoids a patent while maintaining some, or even all, of the performance and value of the patented technology. Designing around a patent can be viewed as a puzzle that requires technical skill, understanding the business value of technology, knowledge of patents, and creativity. Students will also be able to help design patents that cannot be easily designed-around. Not only does this add a valuable new dimension to the students skill set, the course material is organized as a vehicle for refining knowledge of ML and NLP techniques. We will practice by designing around patents on well-known ML and NLP algorithms. Students study the basic algorithm, learn the patents that cover those algorithms, and then experiment with software modifications that avoid the patent while preserving as much of the algorithms performance as possible. In essence, students will view the presence of particular patents as a design constraints, akin to designing for limited memory, bandwidth, or processor speed. Students must have already taken courses in Natural Language Processing (e.g., 11-411) and Machine Learning (e.g., 10-315). Law of Computer Technology 17-562, 17-662, 17-762 or Patents, Licensing, and Innovation 19-473, 19-673 are helpful but not required.

11-646 Applied Legal Analytics & Artificial Intelligence

Spring: 12 units
Technological advances are affecting the legal profession and enable innovation by experts proficient in both law and AI technology. This joint course, co-taught by instructors from the University of Pittsburgh School of Law and Carnegie Mellon Universitys Language Technologies Institute, provides a hands-on practical introduction to the fields of artificial intelligence and law, machine learning, and natural language processing as they are being applied to support the work of legal professionals, researchers, and administrators, such as extracting semantic information from legal documents and using it to solve legal problems. Meanwhile, LegalTech companies and startups have been tapping into the industrys need to make large-scale document analysis tasks more efficient, and to use predictive analytics for better decision making. This course is intended to bring students of law and technical disciplines together into a collaborative classroom setting to learn about the technologies at the intersection of law and AI through lectures and programming exercises, as well as gain practical experience through collaborative project work. Topics in focus include machine learning and natural language applied to legal data, computational models of legal reasoning, and selected legal issues that relate to AI technologies. Students should come from either a (pre-) law background with a strong interest in gaining practical experience with legal analytics, or from a technical discipline with a equally strong interest in tackling the challenges posed by legal analytics tasks and data.

Course Website: https://luimagroup.github.io/appliedlegalanalytics/

11-661 Language and Statistics

Fall: 12 units
Language technologies (search, text mining, information retrieval, speech recognition, machine translation, question answering, biological sequence analysis...) are at the forefront of this century's information revolution. In addition to their use of machine learning, these technologies rely centrally on classic statistical estimation techniques. Yet most CS and engineering undergraduate programs do not prepare students in this area beyond an introductory prob and amp;stats course. This course is designed to plug this hole. The goal of "Language and Statistics" is to ground the data-driven techniques used in language technologies in sound statistical methodology. We start by formulating various language technology problems in both an information theoretic framework (the source-channel paradigm) and a Bayesian framework (the Bayes classifier). We then discuss the statistical properties of words, sentences, documents and whole languages, and the computational formalisms used to represent language. These discussions naturally lead to specific concepts in statistical estimation. Topics include: Zipf's distribution and type-token curves; point estimators, Maximum Likelihood estimation, bias and variance, sparseness, smoothing and clustering; interpolation, shrinkage, and backoff; entropy, cross entropy and mutual information; decision tree models applied to language; latent variable models and the EM algorithm; hidden Markov models; exponential models and maximum entropy; semantic modeling and dimensionality reduction; probabilistic context-free grammars and syntactic language models. The course is designed for LTI and amp; SCS graduate students, but others are welcome. CS UG upperclassmen who've taken it have done well, though they found it challenging. The 11-661 version does not require the course project. Prerequisites: Strong quantitative aptitude. Comfort with basic UG-level probability. Some programming skill.

Course Website: http://www.cs.cmu.edu/~roni/11661/

11-667 Large Language Models Methods and Application

Fall: 12 units
This course provides a broad foundation for understanding, working with, and adapting existing tools and technologies in the area of Large Language Models like BERT, T5, GPT, and others. It begins with a short history of the area of language models and quickly transitions to a broad survey of the area, offering exposure to the gamut of topics including systems, data, data filtering, training objectives, RLHF/instruction tuning, ethics, policy, evaluation, and other human facing issues. Students will delve into Transformer architectures more broadly and how they work, as well as exploring the reasons why they are better than LSTM-based seq2seq, decoding strategies, etc. Students will learn through readings and hands-on assignments where they will explore techniques for pretraining, attention, prompting, etc. They will then apply these skills in a semester-long course project, making use of locally sourced model instances that offer the opportunity to explore behind the curtain of commercial APIs.
Prerequisites: 11-711 or 11-785 or 11-685 or 10-701 or 10-601

11-696 MIIS Capstone Planning Seminar

Spring: 6 units
The MIIS Capstone Planning Seminar prepares students to complete the MIIS Capstone Project in the following semester. Students are organized into teams that will work together to complete the capstone project. They define project goals, requirements, success metrics, and deliverables; and they identify and acquires data, software, and other resources required for successful completion of the project. The planning seminar must be completed in the semester prior to taking the capstone project.

11-697 Introduction to Question Answering with Large Language Models

Fall: 12 units
This course is designed to be accessible to Masters and advanced undergraduate students who seek the basic skills necessary to implement practical Question Answering (QA) applications using Large Language Models (LLMs) in specific information domains. The syllabus includes learning materials on the core concepts of QA and LLMs, and how they are applied in closed commercial systems (e.g. ChatGPT) as well as open systems (e.g. Llama, T5). Students complete a set of hands-on exercises in Python that develop skills in applying LLMs for various open-source QA datasets. The course is also a prerequisite for 11-797 Question Answering (an advanced project-oriented course).

Course Website: https://www.cs.cmu.edu/~ehn/11-697/

11-711 Advanced Natural Language Processing

Fall: 12 units
Advanced natural language processing is an introductory graduate-level course on natural language processing aimed at students who are interested in doing cutting-edge research in the field. In it, we describe fundamental tasks in natural language processing such as syntactic, semantic, and discourse analysis, as well as methods to solve these tasks. The course focuses on modern methods using neural networks, and covers the basic modeling and learning algorithms required therefore. The class culminates in a project in which students attempt to reimplement and improve upon a research paper in a topic of their choosing.

11-716 Graduate Seminar on Dialog Processing

All Semesters: 6 units
Dialog systems and processes are becoming an increasingly vital area of interest both in research and in practical applications. The purpose of this course will be to examine, in a structured way, the literature in this area as well as learn about ongoing work. The course will cover traditional approaches to the problem, as exemplified by the work of Grosz and Sidner, as well as more recent work in dialog, discourse and evaluation, including statistical approaches to problems in the field. We will select several papers on a particular topic to read each week. While everyone will do all readings, a presenter will be assigned to overview the paper and lead the discussion. On occasion, a researcher may be invited to present their own work in detail and discuss it with the group. A student or researcher taking part in the seminar will come away with a solid knowledge of classic work on dialog, as well as familiarity with ongoing trends.

11-721 Grammars and Lexicons

All Semesters: 12 units
Grammars and Lexicons is an introductory graduate course on linguistic data analysis and theory, focusing on methodologies that are suitable for computational implementations. The course covers major syntactic and morphological phenomena in a variety of languages. The emphasis will be on examining both the diversity of linguistic structures and the constraints on variation across languages. Students will be expected to develop and defend analyses of data, capturing linguistic generalizations and making correct predictions within and across languages. The goal is for students to become familiar with the range of phenomena that occur in human languages so that they can generalize the insights into the design of computational systems. The theoretical framework for syntactic and lexical analysis will be Lexical Functional Grammar. Grades will be based on problem sets and take-home exams.

11-722 Grammar Formalisms

Intermittent: 12 units
The goal of this course is to familiarize students with grammar formalisms that are commonly used for research in computational lingusitics, language technologies, and lingusitics. We hope to have students from a variety disciplines (linguistics, computer science, psychology, modern languages, philosophy) in order to cover a broad perspective in class discussions. Comparison of formalisms will lead to a deeper understanding of human language and natural language processing algorithms. The formalisms will include: Head Driven Phrase Structure Grammar, Lexical Functional Grammar, Tree Adjoining Grammar and Categorial Grammar. If time permits, we will cover Penn Treebank, dependency grammar, and Construction Grammar. We will cover the treatment of basic syntactic and semantic phenomena in each formalism, and will also discuss algorithms for parsing and generating sentences for each formalism. If time permits, we may discuss formal language theory and generative capacity. The course is taught jointly by the following faculty of the Language Technologies Institute: Alan Black Alon Lavie Lori Levin (main coordinator)

11-724 Human Language for Artificial Intelligence

Fall: 12 units
An enduring aspect of the quest to build intelligent machines is the challenge of human language. This course introduces students with a background in computer science and a research interest in artificial intelligence fields to the structure of natural language, from sound to society. It covers phonetics (the physical aspects of speech), phonology (the sound-structure of language), morphology (the structure of words), morphosyntax (the use of word and phrase structure to encode meaning), syntactic formalisms (using finite sets of production rules to characterize infinite configurations of structure), discourse analysis and pragmatics (language in discourse and communicative context), and sociolinguistics (language in social context and social meaning). Evaluation is based on seven homework assignments, a midterm examination, and a final examination.

Course Website: http://www.lti.cs.cmu.edu/Courses/11-724-desc.htm

11-731 Machine Translation and Sequence-to-Sequence Models

Spring: 12 units
Instructors: Graham Neubig. Prerequisites: This course has no official pre-requisites, although 11-711 "Algorithms for NLP" or 10-701 "Machine Learning" would be helpful. Course Description: Machine Translation and Sequence-to-Sequence Models is an introductory graduate-level course surveying the primary approaches and methods for developing systems to translate between human languages, or other sequential data. The main objective of the course is to obtain basic understanding and implementation skills for modern methods for MT and sequence transduction, including how to design models, how to learn the model parameters, how to search for the best output, and how to create training data. The course will focus on machine translation, but also briefly cover tasks such as dialog response generation, image caption generation, and others.

11-737 Multilingual Natural Language Processing.

Fall: 12 units
11737 Multilingual Natural Language Processing is an advanced graduate-level course on natural language processing techniques applicable to many languages. Students who take this course should be able to develop linguistically motivated solutions to core and applied NLP tasks for any language. This includes understanding and mitigating the difficulties posed by lack of data in low-resourced languages or language varieties, and the necessity to model particular properties of the language of interest such as complex morphology or syntax. The course will introduce modeling solutions to these issues such as multilingual or cross-lingual methods, linguistically informed NLP models, and methods for effectively bootstrapping systems with limited data or human intervention. The project work will involve building an end-to-end NLP pipeline in a language you don't know.

Course Website: https://www.cs.cmu.edu/~leili/course/11737mnlp23fa/

11-739 Designing Around Patents on Machine Learning and NLP Technology

Spring: 12 units
This course uses Machine Learning and Natural Language Processing as vehicles to teach principles in designing software to avoid patents. After introducing students to the basics of patents, we investigate how to use students software skills to design around patents that is, create new technology that avoids a patent while maintaining some, or even all, of the performance and value of the patented technology. Designing around a patent can be viewed as a puzzle that requires technical skill, understanding the business value of technology, knowledge of patents, and creativity. Students will also be able to help design patents that cannot be easily designed-around. Not only does this add a valuable new dimension to the student's skill set, the course material is organized as a vehicle for refining knowledge of ML and NLP techniques. We will practice by designing around patents on well-known ML and NLP algorithms. Students study the basic algorithm, learn the patents that cover those algorithms, and then experiment with software modifications that avoid the patent while preserving as much of the algorithm's performance as possible. In essence, students will view the presence of particular patents as a design constraints, akin to designing for limited memory, bandwidth, or processor speed. Students must have already taken courses in Natural Language Processing (e.g., 11-411) and Machine Learning (e.g., 10-315). Law of Computer Technology 17-562, 17-662, 17-762 or Patents, Licensing, and Innovation 19-473, 19-673 are helpful but not required.

11-741 Machine Learning with Graphs

Fall and Spring: 12 units
Graphs offer a natural way to represent complex relationships among objects of all kinds. Neural network learning with graphs has become important in both academic research and industrial applications. This course (for graduate and undergraduate students who meet the prerequisites) offers a mixture of fundamental concepts, algorithms, basic and advanced models, and broad applications, ranging from social popularity analysis and knowledge graph reasoning to deep learning for solving NP-complete problems.
Prerequisites: 15-213 and (21-241 or 21-341) and 21-325 and (10-601 or 10-701)

Course Website: https://cmu-ml4graph.github.io/s2024/

11-747 Neural Networks for NLP

All Semesters: 12 units
Neural networks provide powerful new tools for modeling language, and have been used both to improve the state-of-the-art in a number of tasks and to tackle new problems that were not easy in the past. This class will start with a brief overview of neural networks, then spend the majority of the class demonstrating how to apply neural networks to natural language problems. Each section class will introduce a particular problem or phenomenon in natural language, describe why it is difficult to model, and demonstrate several models that were designed to tackle this problem. In the process of doing so, the class will cover different techniques that are useful in creating models, including handling variably sized and structured sentences, efficient handling of large data, semi-supervised and unsupervised learning, structured prediction, and multilingual modeling. There are no official pre-requisites, but a natural language processing course such as 11-411, 11-611, or 11-711, or other experience with implementing natural language processing models is highly recommended.

11-751 Speech Recognition and Understanding

All Semesters: 12 units
The technology to allow humans to communicate by speech with machines or by which machines can understand when humans communicate with each other is rapidly maturing. This course provides an introduction to the theoretical tools as well as the experimental practice that has made the field what it is today. We will cover theoretical foundations, essential algorithms, major approaches, experimental strategies and current state-of-the-art systems and will introduce the participants to ongoing work in representation, algorithms and interface design. This course is suitable for graduate students with some background in computer science and electrical engineering, as well as for advanced undergraduates. Prerequisites: Sound mathematical background, knowledge of basic statistics, good computing skills. No prior experience with speech recognition is necessary. This course is primarily for graduate students in LTI, CS, Robotics, ECE, Psychology, or Computational Linguistics. Others by prior permission of instructor.

11-752 Speech II: Phonetics, Prosody, Perception and Synthesis

Spring: 12 units
The goal of the course is to give the student basic knowledge from several fields that is necessary in order to pursue research in automatic speech processing. The course will begin with a study of the acoustic content of the speech signal. The students will use the spectrographic display to examine the signal and discover its variable properties. Phones in increasingly larger contexts will be studied with the goal of understanding coarticulation. Phonological rules will be studied as a contextual aid in understanding the spectrographic display. The spectrogram will then serve as a first introduction to the basic elements of prosody. Other displays will then be used to study the three parts of prosody: amplitude, duration, and pitch. Building on these three elements, the student will then examine how the three interact in careful and spontaneous speech. Next, the students will explore perception. Topics covered will be: physical aspects of perception, psychological aspects of perception, testing perception processes, practical applications of knowledge about perception. The second part of this course will cover all aspects of speech synthesis. Students need only have a basic knoweldge of speech and language processing. Some degree of programming and statistical modelling will be beneficial, but not required. Taught every other year

11-755 Machine Learning for Signal Processing

Fall: 12 units
Signal Processing is the science that deals with extraction of information from signals of various kinds. This has two distinct aspects and #8212; characterization and categorization. Traditionally, signal characterization has been performed with mathematically-driven transforms, while categorization and classification are achieved using statistical tools. Machine learning aims to design algorithms that learn about the state of the world directly from data. A increasingly popular trend has been to develop and apply machine learning techniques to both aspects of signal processing, often blurring the distinction between the two. This course discusses the use of machine learning techniques to process signals. We cover a variety of topics, from data driven approaches for characterization of signals such as audio including speech, images and video, and machine learning methods for a variety of speech and image processing problems.

11-761 Language and Statistics

Fall: 12 units
Language technologies (search, text mining, information retrieval, speech recognition, machine translation, question answering, biological sequence analysis...) are at the forefront of this century's information revolution. In addition to their use of machine learning, these technologies rely centrally on classic statistical estimation techniques. Yet most CS and engineering undergraduate programs do not prepare students in this area beyond an introductory prob and amp;stats course. This course is designed to plug this hole. The goal of "Language and Statistics" is to ground the data-driven techniques used in language technologies in sound statistical methodology. We start by formulating various language technology problems in both an information theoretic framework (the source-channel paradigm) and a Bayesian framework (the Bayes classifier). We then discuss the statistical properties of words, sentences, documents and whole languages, and the computational formalisms used to represent language. These discussions naturally lead to specific concepts in statistical estimation. Topics include: Zipf's distribution and type-token curves; point estimators, Maximum Likelihood estimation, bias and variance, sparseness, smoothing and clustering; interpolation, shrinkage, and backoff; entropy, cross entropy and mutual information; decision tree models applied to language; latent variable models and the EM algorithm; hidden Markov models; exponential models and maximum entropy; semantic modeling and dimensionality reduction; probabilistic context-free grammars and syntactic language models. The course is designed for LTI and amp; SCS graduate students, but others are welcome. CS UG upperclassmen who've taken it have done well, though they found it challenging. The 11-661 version does not require the course project. Prerequisites: Strong quantitative aptitude. Comfort with basic UG-level probability. Some programming skill.

Course Website: http://www.cs.cmu.edu/~roni/11761/

11-762 Language and Statistics II

Fall: 12 units
This course will cover modern empirical methods in natural language processing. It is designed for language technologies students who want to understand statistical methodology in the language domain, and for machine learning students who want to know about current problems and solutions in text processing. Students will, upon completion, understand how statistical modeling and learning can be applied to text, be able to develop and apply new statistical models for problems in their own research, and be able to critically read papers from the major related conferences (EMNLP and ACL). A recurring theme will be the tradeoffs between computational cost, mathematical elegance, and applicability to real problems. The course will be organized around methods, with concrete tasks introduced throughout. The course is designed for SCS graduate students. Prerequisite: Language and Statistics (11-761) or permission of the instructor. Recommended: Algorithms for Natural Language Processing (11-711), Machine Learning (15-681, 15-781, or 11-746).
Prerequisite: 11-761

11-763 Structured Prediction for Language and other Discrete Data

Fall: 12 units
This course seeks to cover statistical modeling techniques for discrete, structured data such as text. It brings together content previously covered in Language and Statistics 2 (11-762) and Information Extraction (10-707 and 11-748), and aims to define a canonical set of models and techniques applicable to problems in natural language processing, information extraction, and other application areas. Upon completion, students will have a broad understanding of machine learning techniques for structured outputs, will be able to develop appropriate algorithms for use in new research, and will be able to critically read related literature. The course is organized around methods, with example tasks introduced throughout.

Course Website: http://www.cs.cmu.edu/~nasmith/SPFLODD/

11-776 Multimodal Affective Computing

Fall: 12 units
Humans are highly social creatures and have evolved complex mechanisms for signaling information about their thoughts, feelings, and intentions (both deliberately and reflexively). In turn, humans have also evolved complex mechanisms for receiving these signals and inferring the thoughts, feelings, and intentions of others. Proper understanding of human behavior, in all its nuance, requires careful consideration and integration of verbal, vocal, and visual information. These communication dynamics have long been studied in psychology and other social sciences. More recently, the field of multimodal affective computing has sought to enhance these studies using techniques from computer science and artificial intelligence. Common topics of study in this field include affective states, cognitive states, personality, psychopathology, social processes, and communication. As such, multimodal affective computing has broad applicability in both scientific and applied settings ranging from medicine and education to robotics and marketing. The objectives of this course are: (1) To give an overview of the components of human behavior (verbal, vocal, and visual) and the computer science areas that measure them (NLP, speech processing, and computer vision) (2) To provide foundational knowledge of psychological constructs commonly studied in multimodal affective computing (e.g., emotion, personality, and psychopathology) (3) To provide practical instruction on using statistical tools to study research hypotheses (4) To provide information about computational predictive models that integrate multimodal information from the verbal, vocal, and visual modalities (5) To give students practical experience in the computational study of human behavior and psychological constructs through an in-depth course project

11-777 Multimodal Machine Learning

Fall: 12 units
Multimodal machine learning (MMML) is a vibrant multi-disciplinary research field which addresses some of the original goals of artificial intelligence by integrating and modeling multiple communicative modalities, including linguistic, acoustic and visual messages. With the initial research on audio-visual speech recognition and more recently with language vision projects such as image and video captioning, this research field brings some unique challenges for multimodal researchers given the heterogeneity of the data and the contingency often found between modalities. The course will present the fundamental mathematical concepts in machine learning and deep learning relevant to the five main challenges in multimodal machine learning: (1) multimodal representation learning, (2) translation and amp; mapping, (3) modality alignment, (4) multimodal fusion and (5) co-learning. These include, but not limited to, multimodal auto-encoder, deep canonical correlation analysis, multi-kernel learning, attention models and multimodal recurrent neural networks. We will also review recent papers describing state-of-the-art probabilistic models and computational algorithms for MMML and discuss the current and upcoming challenges. The course will discuss many of the recent applications of MMML including multimodal affect recognition, image and video captioning and cross-modal multimedia retrieval. This is a graduate course designed primarily for PhD and research master students at LTI, MLD, CSD, HCII and RI; others, for example (undergraduate) students of CS or from professional master programs, are advised to seek prior permission of the instructor. It is required for students to have taken an introduction machine learning course such as 10-401, 10-601, 10-701, 11-663, 11-441, 11-641 or 11-741. Prior knowledge of deep learning is recommended."

Course Website: https://piazza.com/cmu/fall2018/11777/home (https://piazza.com/cmu/fall2018/11777/home/)

11-792 Intelligent Information Systems Project - HEINZ STUDENTS ONLY

Spring: 12 units
The Software Engineering for IS sequence combines classroom material and assignments in the fundamentals of software engineering (11-791) with a self-paced, faculty-supervised directed project (11-792). The two courses cover all elements of project design, implementation, evaluation, and documentation. Students may elect to take only 11-791; however, if both parts are taken, they should be taken in proper sequence. Prerequisite: 11-791. The course is required for VLIS students.
Prerequisites: 11-791 or 15-393

11-801 Quantitative Evaluation of Language Technologies

Spring: 12 units
Evaluating NLP models for properties like quality, fluency, safety, or revenue generation is a fundamental part of model development in research and engineering contexts. This course will present fundamental principles of evaluation, focusing on both offline contexts such as benchmark datasets and online environments such as production systems. Material will be organized into two parts. The first part will focus on measurement of system decisions, covering the principles of metric design (i.e., what makes a metric appropriate for a given NLP task), data elicitation (i.e., how can we gather data associated with what we are trying to measure), and modeling system properties (i.e., how can we formally model the properties like quality). The second part will focus on comparing systems given a set of measured values. We will cover dataset construction and hypothesis testing in both offline and online contexts. The course will include lectures from external researchers and practitioners using evaluation techniques to audit systems, design new benchmarks, and deploy production models.

11-824 Subword Modeling

Intermittent: 12 units
The goal of this course is to lead students to engage broadly with the existing NLP and computational linguistics research on subword modeling and develop new computational approaches to problems in morphology, orthography, and phonology. In addition to three other miniprojects, students will be expected to produce one piece of research that can be developed into a conference or workshop paper (though submission is not a course requirement). The paper should be suitable for the Phonology, Morphology, and Word Segmentation tracks of the *ACL conferences, the SIGMORPHON workshop, Coling, or LREC.
Prerequisites: 11-711 or 11-611 or 11-411

11-851 Talking to Robots

Fall
Household robots need to move beyond simple programmed tasks like those a roomba, and become full-fledged digital assistants. A robotic agent that exists (physically) in the world, gains access to rich and personalized knowledge of its environment. How much do things weigh? What's fragile? Where you store the extra chocolates that you don't want anyone to find because they are just for you. Building an agent that can accomplish tasks requires the integration of a diverse set of technologies and engineering. Language models, SLAM, semantic mapping, task planning, understanding affordances, and end effector control. This course will cover both foundational works in grounding language to action and analyze (or reimplement) state-of-the-art Large Language Model based task planners.

Course Website: https://talkingtorobots.com/11-851/

11-868 Large Language Model Systems

Spring: 12 units
Recent progress of Artificial Intelligence has been largely driven by advances in large language models (LLMs) and other generative methods. These models are often very large (e.g. 175 billion parameters for GPT3) and requires increasingly larger data to train (e.g. 300 billion tokens for ChatGPT). Training, serving, fine-tuning, and evaluating LLMs require sophisticated engineering with modern hardware and software stacks. Developing scalable systems for large language models is critical to advance AI. In this course, students will learn the essential skills to design and implement LLM systems. This includes algorithms and system techniques to efficiently train LLMs with huge data, efficient embedding storage and retrieval, data efficient fine-tuning, communication efficient algorithms, efficient implementation of reinforcement learning with human feedback, acceleration on GPU and other hardware, model compression for deployment, and online maintenance. We will cover the latest advances about LLM systems in machine learning, natural language processing, and system research.
Prerequisites: 11-711 and 11-785

Course Website: https://llmsystem.github.io/

11-877 Advanced Topics in Multimodal Machine Learning

Spring
This course is designed to be a graduate-level course covering recent research papers in multimodal machine learning, a vibrant multi-disciplinary research field which studies modeling, alignment, and fusion of heterogeneous data from multiple modalities, including language, vision, and acoustic. The course will focus on discussions and understanding of recent research papers in this field. Students are expected to have already taken 11-777 Multimodal Machine Learning course or have equivalent research experience (instructor approval required). The course is planned for 6 credit units. Optionally, students can register for 12 credit units, with the expectation to do a comprehensive research project as part of the semester. These course projects are expected to be done in teams, with the research topic to be in the realm of multimodal machine learning and pre-approved by the course instructors.
Prerequisite: 11-777 Min. grade C

11-891 Neural Code Generation

Spring
This course is a graduate-level course introducing research topics in neural code generation: modeling and synthesizing programs using deep-learning methods, with an emphasis on neural language models. The course covers (1) foundational advances in neural language models that are relevant to code generation (2) code-specific formal methods for training, inference, and evaluation and (3) research frontiers such as long document lengths, domain adaptation, and downstream interactive and production-ready uses of the final code generation models. The course combines lectures and paper discussions, as well as a final research project for students taking the course for 12 units. This is a graduate course designed primarily for PhD and research master students at LTI, S3D, MLD, CSD, HCII and RI; others, for example (undergraduate) students of CS or from professional master programs, are advised to seek prior permission of the instructors. It is required for students to have taken an introductory ML course or an ML project-based course such as 10-401, 10-601, 10-701, 11-663, 11-441, 11-641, 11-667, 11-741, 11-711, or 11-777. Prior knowledge of deep learning is recommended.

11-927 MIIS Capstone Project

Fall: 36 units
The capstone project course is a group-oriented demonstration of student skill in one or more areas covered by the degree. Typically the result of the capstone project is a major software application. The capstone project course consists of two components. The classroom component guides students in project planning, team management, development of requirements and design specifications, and software tools for managing group-oriented projects. The lab component provides project-specific technical guidance and expertise, for example in the development of a question answering system, dialog, or sentiment analysis application. Thus, each project receives two types of supervision, often from two separate members of the faculty.

Machine Learning Courses

10-301 Introduction to Machine Learning

Fall and Spring: 12 units
Machine Learning is concerned with computer programs that automatically improve their performance through experience (e.g., programs that learn to recognize human faces, recommend music and movies, and drive autonomous robots). This course covers the theory and practical algorithms for machine learning from a variety of perspectives. We cover topics such as decision tree learning, neural networks, statistical learning methods, unsupervised learning and reinforcement learning. The course covers theoretical concepts such as inductive bias, the PAC learning framework, Bayesian learning methods, and Occam's Razor. Programming assignments include hands-on experiments with various learning algorithms. This course is designed to give a graduate-level student a thorough grounding in the methodologies, technologies, mathematics and algorithms currently needed by people who do research in machine learning. 10-301 and 10-601 are identical. Undergraduates must register for 10-301 and graduate students must register for 10-601. 10-301 is recommended for undergraduates who are not SCS majors. (SCS majors should instead take 10-315.)
Prerequisites: 15-122 Min. grade C and (15-151 Min. grade C or 21-128 Min. grade C or 21-127 Min. grade C) and (36-217 Min. grade C or 21-325 Min. grade C or 36-235 Min. grade C or 15-359 Min. grade C or 36-218 Min. grade C or 36-225 Min. grade C or 36-220 Min. grade C or 15-259 Min. grade C or 36-219 Min. grade C)

Course Website: http://mlcourse.org

10-315 Introduction to Machine Learning (SCS Majors)

Fall and Spring: 12 units
Machine learning is a subfield of computer science with the goal of exploring, studying, and developing learning systems, methods, and algorithms that can improve their performance with learning from data. This course is designed to give undergraduate students a one-semester-long introduction to the main principles, algorithms, and applications of machine learning and is specifically designed for the SCS undergrad majors. After completing the course, students will be able to: *select and apply an appropriate supervised learning algorithm for classification problems and understand its underlying assumptions (e.g., naive Bayes, perceptron, support vector machine, logistic regression). *select and apply an appropriate supervised learning algorithm for regression problems and understand its underlying assumptions (e.g., linear regression, ridge regression). *recognize different types of unsupervised learning problems, and select and apply appropriate algorithms (e.g., clustering, linear and nonlinear dimensionality reduction). *work with probabilities (Bayes rule, conditioning, expectations, independence), linear algebra (vector and matrix operations, eigenvectors), and calculus (gradients) to derive machine learning methods such as linear regression, naive Bayes, and principal components analysis. *understand machine learning principles such as model selection, overfitting, and underfitting, and techniques such as cross-validation and regularization. *implement machine learning algorithms such as logistic regression via stochastic gradient descent, linear regression (using a linear algebra toolbox), perceptron, or k-means clustering. *run appropriate supervised and unsupervised learning algorithms on real and synthetic data sets and interpret the results.
Prerequisites: 15-122 Min. grade C and (21-128 Min. grade C or 15-151 Min. grade C or 21-127 Min. grade C) and (15-259 Min. grade C or 21-325 Min. grade C or 15-359 Min. grade C or 36-219 Min. grade C or 36-235 Min. grade C or 36-217 Min. grade C or 36-225 Min. grade C or 36-218 Min. grade C) and (21-240 Min. grade C or 21-241 Min. grade C or 21-242 Min. grade C)

Course Website: https://goo.gl/mmR2eL (https://goo.gl/mmR2eL/)

10-335 Art and Machine Learning

Intermittent: 12 units
ARS, the Latin origin of the word 'art', encompasses both Art and Science. Over time, these two disciplines, once separated, are now converging in various area. One such intersection is the fusion of art and machine learning. In recent years, art has been propelled forward by the rapid advancements in technology and scientific discoveries, while machine learning (ML) stands at the forefront of computer science innovation. The increasing popularity and accessibility of neural network-based AI models have garnered significant attention for the amalgamation of art and ML techniques. This project-based course is designed to introduce the synergy between art and machine learning to a wide range of students, including majoring in art and computer science. We will impart knowledge through examples, technologies, and discussions that bridge the realms of art and machine learning. Students will explore example codes and make creative applications and artworks using ML methods. No prior knowledge of machine learning or experience in art practice is required, but students should have a basic understanding of Python. Additionally, an open-minded approach is essential, as occasionally we will delve into the necessary mathematical foundations and engage in discussions on the conceptual development and artistic value of your projects.

Course Website: https://sites.google.com/view/artml23s (https://sites.google.com/view/artml23s/)

10-403 Deep Reinforcement Learning & Control

Spring: 12 units
This course brings together many disciplines of Artificial Intelligence (including computer vision, robot control, reinforcement learning, language understanding) to show how to develop intelligent agents that can learn to sense the world and learn to act by imitating others, maximizing sparse rewards, and/or satisfying their curiosity.
Prerequisites: 10-401 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C or 10-601 Min. grade C or 10-701 Min. grade C

Course Website: https://cmudeeprl.github.io/Spring202010403website/

10-405 Machine Learning with Large Datasets (Undergraduate)

Spring: 12 units
Large datasets are difficult to work with for several reasons. They are difficult to visualize, and it is difficult to understand what sort of errors and biases are present in them. They are computationally expensive to process, and often the cost of learning is hard to predict - for instance, and algorithm that runs quickly in a dataset that fits in memory may be exorbitantly expensive when the dataset is too large for memory. Large datasets may also display qualitatively different behavior in terms of which learning methods produce the most accurate predictions. This course is intended to provide a student practical knowledge of, and experience with, the issues involving large datasets. Among the issues considered are: scalable learning techniques, such as streaming machine learning techniques; parallel infrastructures such as map-reduce; practical techniques for reducing the memory requirements for learning methods, such as feature hashing and Bloom filters; and techniques for analysis of programs in terms of memory, disk usage, and (for parallel methods) communication complexity. The class will include programming assignments, and a one-month short project chosen by the student. The project will be designed to compare the scalability of variant learning algorithms on datasets. An introductory course in machine learning, like 10-601 or 10-701, is a prerequisite or a co-requisite. If you plan to take this course and 10-601 concurrently please tell the instructor. The course will include several substantial programming assignments, so an additional prerequisite is 15-211, or 15-214, or comparable familiarity with Python and good programming skills.
Prerequisites: (15-211 or 17-214 or 15-214 or 15-210) and (10-401 or 10-301 or 10-715 or 10-701 or 10-315 or 10-601)

Course Website: https://10605.github.io/

10-414 Deep Learning Systems: Algorithms and Implementation

Intermittent: 12 units
The goal of this course is to provide students an understanding and overview of the "full stack" of deep learning systems, ranging from the high-level modeling design of modern deep learning systems, to the basic implementation of automatic differentiation tools, to the underlying device-level implementation of efficient algorithms. Throughout the course, students will design and build from scratch a complete deep learning library, capable of efficient GPU-based operations, automatic differentiation of all implemented functions, and the necessary modules to support parameterized layers, loss functions, data loaders, and optimizers. Using these tools, students will then build several state-of-the-art modeling methods, including convolutional networks for image classification and segmentation, recurrent networks and self-attention models for sequential tasks such as language modeling, and generative models for image generation.
Prerequisites: (15-213 Min. grade C or 15-513 Min. grade C) and (21-240 Min. grade C or 21-241 Min. grade C) and (15-151 Min. grade C or 21-127 Min. grade C or 21-128 Min. grade C) and (10-301 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C or 10-315 Min. grade C or 10-715 Min. grade C)

10-417 Intermediate Deep Learning

Fall: 12 units
Building intelligent machines that are capable of extracting meaningful representations from data lies at the core of solving many AI related tasks. In the past decade, researchers across many communities, from applied statistics to engineering, computer science and neuroscience, have developed deep models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. The goal of this course is to introduce students to both the foundational ideas and the recent advances in deep learning. The first part of the course will focus on supervised learning, including neural networks, back-propagation algorithm, convolutional models, recurrent neural networks, and their extensions with applications to image recognition, video analysis, and language modelling. The second part of the course will cover unsupervised learning, including variational autoencoders, sparse-coding, Boltzmann machines, and generative adversarial networks. This course will assume a reasonable degree of mathematical maturity and will require strong programming skills.

Prerequisites: 10-701 Min. grade C or 10-601 Min. grade C or 10-301 Min. grade C or 10-315 Min. grade C or 10-715 Min. grade C

Course Website: https://deeplearning-cmu-10417.github.io

10-418 Machine Learning for Structured Data

Intermittent: 12 units
A key challenge in machine learning is that of structured prediction: taking unstructured data as input and producing a structured output. Structured prediction problems abound throughout application areas such as natural language processing, speech processing, computational biology, computer vision, healthcare, and many others. In this course, we will study modern approaches to structured prediction building on probabilistic graphical models, deep learning, and search. The course will focus on three key aspects: models, inference, and learning. The models we consider will focus on both generative and discriminative models such as Bayesian networks, Markov random fields (MRFs), conditional random fields (CRFs), and deep neural networks including convolutional neural networks (CNNs) and recurrent neural networks (RNNs) and #8212; as well as hybrids of graphical models and neural networks. The course will explore approaches to exact and approximate inference: junction tree algorithm, approximate marginal inference by Markov chain Monte Carlo (MCMC) and variational methods, approximate MAP inference by integer linear programming (ILP) and search. We will explore unsupervised, semi-supervised, and supervised learning using different formulations of the learning problem: MLE, Bayesian inference, structured perceptron, M3Ns, learning to search, and autoencoders. Covered applications will include machine translation, speech recognition, DNA sequence analysis, scene understanding, medical diagnosis. This course is cross-listed as 10-418 and 10-618; students registered for 10-618 will do a course project.
Prerequisites: 10-715 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C or 10-401 Min. grade C or 10-301 Min. grade C or 10-315 Min. grade C

10-422 Foundations of Learning, Game Theory, and Their Connections

Intermittent: 12 units
In the past decades, researchers have discovered a number of important and deep connections between machine learning theory and algorithmic game theory. This course will explore these connections, both introducing fundamental topics in each area and describing how ideas from each area can shed light on the other.
Prerequisites: (36-218 Min. grade C or 36-217 Min. grade C or 15-259 Min. grade C or 21-325 Min. grade C or 36-225 Min. grade C or 36-219 Min. grade C) and (15-251 Min. grade C or 10-601 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C) and (21-240 Min. grade C or 21-241 Min. grade C or 21-242 Min. grade C)

10-423 Generative AI

Intermittent: 12 units
From generating images and text to generating music and art, the goal of generative modeling has long been a key challenge for artificial intelligence. This course explores the techniques from machine learning and artificial intelligence that are driving the recent advances in generative modeling and foundation models. Students will understand, develop, and apply state-of-the-art algorithms that enable machines to generate realistic and creative content. Core topics will include: the fundamental mechanisms of learning; how to build generative models and other large foundation models (e.g. transformers for vision and language, diffusion models); how to train such models (pre-training, fine-tuning) and efficiently adapt them (adapters, in-context learning); how to scale up to massive datasets (multi-GPU/distributed optimization); how to employ existing models for everyday use (generating code, coding with a generative model in the loop). Students will also explore the theoretical foundations and empirical attempts to understand their inner workings as well as learn about the ways in which things can go wrong (bias, hallucination, adversarial attacks, data contamination) and ways to combat these problems. Students in the course will develop understanding of modern techniques through implementation, but they will also employ existing libraries and models to explore their generative capabilities and limitations. The course is designed for students who have completed an introductory course in machine learning or deep learning.
Prerequisites: 10-601 Min. grade C or 10-701 Min. grade C or 10-715 Min. grade C or 11-485 Min. grade C or 11-685 Min. grade C or 10-301 Min. grade C or 11-785 Min. grade C or 10-315 Min. grade C

Course Website: https://www.cs.cmu.edu/~mgormley/courses/10423 (https://www.cs.cmu.edu/~mgormley/courses/10423/)

10-425 Introduction to Convex Optimization

Intermittent: 12 units
As machine learning grows in prominence, so also has optimization become a mainstay for machine learning, particularly techniques for convex optimization. Most learning problems are formulated as optimization of some objective function, sometimes subject to constraints. This course explores the optimization algorithms used to solve these machine learning problems. We characterize the properties of the optimization problems that enable these techniques to be efficient (e.g. convexity, smoothness, linearity, separability) as well as properties that inhibit efficient optimization (e.g. nonconvexity). Core topics include first order methods (gradient descent, subgradient methods, proximal and stochastic gradient descent), duality and linear programming, and second-order/quasi-Newton methods. We also consider advanced techniques ranging from those that have spurred the growth of deep learning (e.g. adaptive gradient methods, momentum) and those that enable large-scale distributed optimization. The course will focus both on theory and practical applications, frequently drawing motivation from examples in machine learning. The course is designed so that a machine learning (ML) course could be taken after or before this one; ML is not a prerequisite. Students will gain the tools to both implement and analyze modern optimization techniques.
Prerequisites: (21-240 Min. grade C or 21-241 Min. grade C) and (21-325 Min. grade C or 36-219 Min. grade C or 36-217 Min. grade C or 15-359 Min. grade C) and (21-254 Min. grade C or 11-485 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C or 21-256 Min. grade C or 21-259 Min. grade C) and (15-151 Min. grade C or 21-127 Min. grade C) and 15-122 Min. grade C

Course Website: https://www.cs.cmu.edu/~mgormley/courses/10425 (https://www.cs.cmu.edu/~mgormley/courses/10425/)

10-500 Senior Research Project

All Semesters
Register for this course if you are minoring in Machine Learning. This course is intended for research with a faculty member that would count towards the minor.

10-520 Independent Study

All Semesters
Independent Study intended to work on research with a Machine Learning faculty member.

10-600 Mathematical background for Machine Learning

Fall and Spring: 12 units
This course provides a place for students to practice the necessary mathematical background for further study in machine learning and #8212; particularly for taking 10-601 and 10-701. Topics covered include probability, linear algebra (inner product spaces, linear operators), multivariate differential calculus, optimization, and likelihood functions. The course assumes some background in each of the above, but will review and give practice in each. (It does not provide from-scratch coverage of all of the above, which would be impossible in a course of this length.) Some coding will be required: the course will provide practice with translating the above mathematical concepts into concrete programs. This course supersedes the two mini-courses 10-606 and 10-607.

10-601 Introduction to Machine Learning (Master's)

Fall and Spring: 12 units
Machine Learning is concerned with computer programs that automatically improve their performance through experience (e.g., programs that learn to recognize human faces, recommend music and movies, and drive autonomous robots). This course covers the theory and practical algorithms for machine learning from a variety of perspectives. We cover topics such as decision tree learning, neural networks, statistical learning methods, unsupervised learning and reinforcement learning. The course covers theoretical concepts such as inductive bias, the PAC learning framework, Bayesian learning methods, and Occam's Razor. Programming assignments include hands-on experiments with various learning algorithms. This course is designed to give a graduate-level student a thorough grounding in the methodologies, technologies, mathematics and algorithms currently needed by people who do research in machine learning. 10-301 and 10-601 are identical. Undergraduates must register for 10-301 and graduate students must register for 10-601. 10-301 is recommended for undergraduates who are not SCS majors. (SCS majors should instead take 10-315.)
Prerequisites: 15-122 Min. grade C and (21-127 Min. grade C or 21-128 Min. grade C or 15-151 Min. grade C) and (36-219 Min. grade C or 36-218 Min. grade C or 36-217 Min. grade C or 15-259 Min. grade C or 36-220 Min. grade C or 36-235 Min. grade C or 21-325 Min. grade C or 15-359 Min. grade C or 36-225 Min. grade C)

Course Website: http://mlcourse.org

10-605 Machine Learning with Large Datasets

Fall and Spring: 12 units
Large datasets are difficult to work with for several reasons. They are difficult to visualize, and it is difficult to understand what sort of errors and biases are present in them. They are computationally expensive to process, and often the cost of learning is hard to predict - for instance, and algorithm that runs quickly in a dataset that fits in memory may be exorbitantly expensive when the dataset is too large for memory. Large datasets may also display qualitatively different behavior in terms of which learning methods produce the most accurate predictions. This course is intended to provide a student practical knowledge of, and experience with, the issues involving large datasets. Among the issues considered are: scalable learning techniques, such as streaming machine learning techniques; parallel infrastructures such as map-reduce; practical techniques for reducing the memory requirements for learning methods, such as feature hashing and Bloom filters; and techniques for analysis of programs in terms of memory, disk usage, and (for parallel methods) communication complexity. The class will include programming assignments, and a one-month short project chosen by the student. The project will be designed to compare the scalability of variant learning algorithms on datasets. An introductory course in machine learning, like 10-601 or 10-701, is a prerequisite or a co-requisite. If you plan to take this course and 10-601 concurrently please tell the instructor. The course will include several substantial programming assignments, so an additional prerequisite is 15-211, or 15-214, or comparable familiarity with Python and good programming skills.
Prerequisites: (15-211 or 17-214 or 15-210 or 15-214) and (10-601 or 10-401 or 10-715 or 10-701 or 10-301 or 10-315)

Course Website: https://10605.github.io/

10-606 Mathematical Foundations for Machine Learning

Fall: 6 units
This course provides a place for students to practice the necessary mathematical background for further study in machine learning. Topics covered include probability (random variables, modeling with continuous and discrete distributions), linear algebra (inner product spaces, linear operators), and multivariate differential calculus (partial derivatives, matrix differentials). The course assumes some background in each of the above, but will review and give practice in each. (It does not provide from-scratch coverage of all of the above, which would be impossible in a course of this length.) Some coding will be required: the course will provide practice with translating the above mathematical concepts into concrete programs. This course is one of two minis intended to prepare students for further study in machine learning and #8212; particularly for taking 10-601 and 10-701. One of the courses 10-606 focuses on mathematical background, and the other course 10-607 focuses on computational background. Most students take both mini courses, but this is not required. 10-606 is not a prerequisite of 10-607.

10-607 Computational Foundations for Machine Learning

Fall: 6 units
This course provides a place for students to practice the necessary computational background for further study in machine learning. Topics covered include computational complexity, analysis of algorithms, proof techniques, optimization, dynamic programming, recursion, and data structures. The course assumes some background in each of the above, but will review and give practice in each. (It does not provide from-scratch coverage of all of the above, which would be impossible in a course of this length.) Some coding will be required: the course will provide practice with translating the above computational concepts into concrete programs. This course is one of two minis intended to prepare students for further study in machine learning and #8212; particularly for taking 10-601 and 10-701. One of the courses 10-606 focuses on mathematical background, and the other course 10-607 focuses on computational background. Most students take both mini courses, but this is not required. 10-606 is not a prerequisite of 10-607.

10-608 Conversational Machine Learning

Intermittent: 12 units
Machine Learning today is largely about finding patterns in large amounts of data. But as personal devices that interact with us in natural language become ubiquitous (e.g., Siri, Google Now), they open an amazing possibility of letting users teach machines in natural language, similar to how we teach each other. Conversation, as an interface to machine learning systems, opens a new paradigm that both unifies several existing machine learning paradigms (e.g., active learning, supervised learning), but also brings a unique set of advantages and challenges that lie at the intersection of machine learning and natural language processing. This course will be structured as a well-defined mini-challenge (project) course. We will present you with several well-defined open problems and provide you with recently collected datasets that can get you started immediately! But you will be free to define your own problem using that data as well, or come up with your own problem entirely. There are no other constraints, and since this is a new area of research, you can (and should) be creative and as crazy in coming up with methods to tackle them. At the same time, we will provide guidance via readings and class-based hacking sessions. This course is a great way to get introduced to open problems in a collaborative and structured environment. Challenges Building a classifier with zero examples. Telling sequence to sequence models about their mistakes Letting machine learning models ask questions
Prerequisites: 10-715 Min. grade C or 10-601 Min. grade C or 10-401 Min. grade C or 10-701 Min. grade C

10-613 Machine Learning Ethics and Society

Intermittent: 12 units
The practice of Machine Learning (ML) increasingly involves making choices that impact real people and society at large. This course covers an array of ethical, societal, and policy considerations in applying ML tools to high-stakes domains, such as employment, education, lending, criminal justice, medicine, and beyond. We will discuss: (1) the pathways through which ML can lead to or amplify problematic decision-making practices (e.g., those exhibiting discrimination, inscrutability, invasion of privacy, and beyond); (2) recent technological methods and remedies to capture and alleviate these concerns; and (3) the scope of applicability and limitations of technological remedies in the context of several contemporary application domains. The course's primary goals are: (a) to raise awareness about the social, ethical, and policy implications of ML, and (b) to prepare students to critically analyze these issues as they emerge in the ever-expanding use of ML in socially consequential domains.
Prerequisites: 10-315 or 10-601 or 10-715 or 10-701 or 10-301

Course Website: http://www.cs.cmu.edu/~hheidari/mles-spring-23.html

10-617 Intermediate Deep Learning

Fall: 12 units
Building intelligent machines that are capable of extracting meaningful representations from data lies at the core of solving many AI related tasks. In the past decade, researchers across many communities, from applied statistics to engineering, computer science and neuroscience, have developed deep models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. The goal of this course is to introduce students to both the foundational ideas and the recent advances in deep learning. The first part of the course will focus on supervised learning, including neural networks, back-propagation algorithm, convolutional models, recurrent neural networks, and their extensions with applications to image recognition, video analysis, and language modelling. The second part of the course will cover unsupervised learning, including variational autoencoders, sparse-coding, Boltzmann machines, and generative adversarial networks. This course will assume a reasonable degree of mathematical maturity and will require strong programming skills.

Prerequisites: 10-601 Min. grade C or 10-701 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C or 10-715 Min. grade C

Course Website: https://deeplearning-cmu-10417.github.io

10-618 Machine Learning for Structured Data

Intermittent: 12 units
A key challenge in machine learning is that of structured prediction: taking unstructured data as input and producing a structured output. Structured prediction problems abound throughout application areas such as natural language processing, speech processing, computational biology, computer vision, healthcare, and many others. In this course, we will study modern approaches to structured prediction building on probabilistic graphical models, deep learning, and search. The course will focus on three key aspects: models, inference, and learning. The models we consider will focus on both generative and discriminative models such as Bayesian networks, Markov random fields (MRFs), conditional random fields (CRFs), and deep neural networks including convolutional neural networks (CNNs) and recurrent neural networks (RNNs) and #8212; as well as hybrids of graphical models and neural networks. The course will explore approaches to exact and approximate inference: junction tree algorithm, approximate marginal inference by Markov chain Monte Carlo (MCMC) and variational methods, approximate MAP inference by integer linear programming (ILP) and search. We will explore unsupervised, semi-supervised, and supervised learning using different formulations of the learning problem: MLE, Bayesian inference, structured perceptron, M3Ns, learning to search, and autoencoders. Covered applications will include machine translation, speech recognition, DNA sequence analysis, scene understanding, medical diagnosis. This course is cross-listed as 10-418 and 10-618; students registered for 10-618 will do a course project.
Prerequisites: 10-301 Min. grade C or 10-715 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C or 10-315 Min. grade C or 10-401 Min. grade C

10-623 Generative AI

Intermittent: 12 units
From generating images and text to generating music and art, the goal of generative modeling has long been a key challenge for artificial intelligence. This course explores the techniques from machine learning and artificial intelligence that are driving the recent advances in generative modeling and foundation models. Students will understand, develop, and apply state-of-the-art algorithms that enable machines to generate realistic and creative content. Core topics will include: the fundamental mechanisms of learning; how to build generative models and other large foundation models (e.g. transformers for vision and language, diffusion models); how to train such models (pre-training, fine-tuning) and efficiently adapt them (adapters, in-context learning); how to scale up to massive datasets (multi-GPU/distributed optimization); how to employ existing models for everyday use (generating code, coding with a generative model in the loop). Students will also explore the theoretical foundations and empirical attempts to understand their inner workings as well as learn about the ways in which things can go wrong (bias, hallucination, adversarial attacks, data contamination) and ways to combat these problems. Students in the course will develop understanding of modern techniques through implementation, but they will also employ existing libraries and models to explore their generative capabilities and limitations. The course is designed for students who have completed an introductory course in machine learning or deep learning.
Prerequisites: 10-301 Min. grade C or 11-785 Min. grade C or 11-685 Min. grade C or 11-485 Min. grade C or 10-715 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C or 10-315 Min. grade C

Course Website: https://www.cs.cmu.edu/~mgormley/courses/10423 (https://www.cs.cmu.edu/~mgormley/courses/10423/)

10-625 Introduction to Convex Optimization

Intermittent: 12 units
As machine learning grows in prominence, so also has optimization become a mainstay for machine learning, particularly techniques for convex optimization. Most learning problems are formulated as optimization of some objective function, sometimes subject to constraints. This course explores the optimization algorithms used to solve these machine learning problems. We characterize the properties of the optimization problems that enable these techniques to be efficient (e.g. convexity, smoothness, linearity, separability) as well as properties that inhibit efficient optimization (e.g. nonconvexity). Core topics include first order methods (gradient descent, subgradient methods, proximal and stochastic gradient descent), duality and linear programming, and second-order/quasi-Newton methods. We also consider advanced techniques ranging from those that have spurred the growth of deep learning (e.g. adaptive gradient methods, momentum) and those that enable large-scale distributed optimization. The course will focus both on theory and practical applications, frequently drawing motivation from examples in machine learning. The course is designed so that a machine learning (ML) course could be taken after or before this one; ML is not a prerequisite. Students will gain the tools to both implement and analyze modern optimization techniques.
Prerequisites: (21-240 Min. grade C or 21-241 Min. grade C) and (36-219 Min. grade C or 21-325 Min. grade C or 36-217 Min. grade C or 15-359 Min. grade C) and (10-315 Min. grade C or 21-259 Min. grade C or 10-301 Min. grade C or 21-256 Min. grade C or 21-254 Min. grade C or 11-485 Min. grade C) and (21-127 Min. grade C or 15-151 Min. grade C) and 15-122 Min. grade C

Course Website: https://www.cs.cmu.edu/~mgormley/courses/10425 (https://www.cs.cmu.edu/~mgormley/courses/10425/)

10-701 Introduction to Machine Learning

Fall and Spring: 12 units
Machine learning studies the question: "how can we build adaptive algorithms that automatically improve their performance (on a given task) as they acquire more experience?" This can cover a dizzying array of technologies depending on what sort of task we have in mind, and we take to constitute experience. Through this framing, we might view classical statistics problems, like estimating the likelihood that a coin lands on heads as an ML problem: the task is to produce an estimate, and the experience would consist of observations. But ML can also include robotics challenges, where the experience is acquired dynamically as our artificial agent interacts with the real world. Other grand challenges in machine learning relate to personalized medicine, natural language processing, and most recently generating media artifacts like photographs and essays (but don't ask chatGPT to do your homework). This course is designed to give PhD students a solid foundation in the methods, mathematics, and algorithms of modern machine learning. Students entering the class with a pre-existing working knowledge of probability, statistics and algorithms will be at an advantage, but the class has been designed so that anyone with a strong mathematical and computer science background can catch up and fully participate. If you are interested in this topic, but are not a PhD student, or are a PhD student not specializing in machine learning, you might consider the master's level course on Machine Learning, 10-601. This class may be appropriate for MS and undergrad students who are interested in the theory and algorithms behind ML.
Prerequisites: 15-122 Min. grade C and (21-128 Min. grade C or 15-151 Min. grade C or 21-127 Min. grade C) and (21-325 Min. grade C or 36-217 Min. grade C or 36-219 Min. grade C or 36-225 Min. grade C or 36-218 Min. grade C or 15-259 Min. grade C or 15-359 Min. grade C)

Course Website: https://machinelearningcmu.github.io/F23-10701/

10-702 Statistical Machine Learning

Spring: 12 units
Statistical Machine Learning is a second graduate level course in advanced machine learning, assuming that students have taken Machine Learning (10-701) or Advanced Machine Learning (10-715), and Intermediate Statistics (36-705). The term ?statistical? in the title reflects the emphasis on statistical theory and methodology. This course is mostly focused on methodology and theoretical foundations. It treats both the ?art? of designing good learning algorithms and the ?science? of analyzing an algorithm?s statistical properties and performance guarantees. Theorems are presented together with practical aspects of methodology and intuition to help students develop tools for selecting appropriate methods and approaches to problems in their own research. Though computation is certainly a critical component of what makes a method successful, it will not receive the same central focus as methodology and theory. We will cover topics in statistical theory that are important for researchers in machine learning, including consistency, minimax estimation, and concentration of measure. We will also cover statistical topics that may not be covered in as much depth in other machine learning courses, such as nonparametric density estimation, nonparametric regression, and Bayesian estimation.
Prerequisites: (10-705 or 36-705) and (10-701 or 10-715)

Course Website: http://www.stat.cmu.edu/~larry/=sml/

10-703 Deep Reinforcement Learning & Control

Spring: 12 units
This course will cover latest advances in Reinforcement Learning and Imitation learning. This is a fast developing research field and an official textbook is available only for about one fourth of the course material. The rest will be taught from recent research papers. This course brings together many disciplines of Artificial Intelligence to show how to develop intelligent agent that can learn to sense the world and learn to act imitating others or maximizing sparse rewards Particular focus will be given in incorporating visual sensory input and learning suitable visual state representations.
Prerequisites: 10-315 Min. grade B or 10-401 Min. grade B or 10-301 Min. grade B or 10-701 Min. grade B or 10-601 Min. grade B or 10-715 Min. grade B

Course Website: https://cmudeeprl.github.io/703website/

10-707 Advanced Deep Learning

Fall and Spring: 12 units
Models that are capable of extracting complex, hierarchical representations from high-dimensional data lie at the core of solving many ML and AI domains, such as visual object recognition, information retrieval, natural language processing, and speech perception. While the usefulness of such deep learning techniques is undisputed, our understanding of them is still in many ways nascent. The goal of this course is to introduce students to recent and exciting developments (both theoretical and practical) in these methods. This is an advanced graduate course, designed for Masters and Ph.D. level students, and will assume a substantial degree of mathematical maturity. Prerequisite: ML: 10-701 or 10-715, and strong programming skills.
Prerequisites: 10-715 Min. grade C or 10-401 Min. grade C or 10-315 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C

10-708 Probabilistic Graphical Models

Spring: 12 units
Many of the problems in artificial intelligence, statistics, computer systems, computer vision, natural language processing, and computational biology, among many other fields, can be viewed as the search for a coherent global conclusion from local information. The probabilistic graphical models framework provides an unified view for this wide range of problems, enabling efficient inference, decision-making and learning in problems with a very large number of attributes and huge datasets. This graduate-level course will provide you with a strong foundation for both applying graphical models to complex problems and for addressing core research topics in graphical models. The class will cover three aspects: The core representation, including Bayesian and Markov networks, and dynamic Bayesian networks; probabilistic inference algorithms, both exact and approximate; and, learning methods for both the parameters and the structure of graphical models. Students entering the class should have a pre-existing working knowledge of probability, statistics, and algorithms, though the class has been designed to allow students with a strong numerate background to catch up and fully participate. It is expected that after taking this class, the students should have obtain sufficient working knowledge of multi-variate probabilistic modeling and inference for practical applications, should be able to formulate and solve a wide range of problems in their own domain using GM, and can advance into more specialized technical literature by themselves. Students are required to have successfully completed 10701 or 10715, or an equivalent class.
Prerequisites: 10-701 Min. grade C or 10-601 Min. grade C or 10-301 Min. grade C or 10-315 Min. grade C or 10-715 Min. grade C

Course Website: https://andrejristeski.github.io/10708-22/

10-714 Deep Learning Systems: Algorithms and Implementation

Fall: 12 units
The goal of this course is to provide students an understanding and overview of the "full stack" of deep learning systems, ranging from the high-level modeling design of modern deep learning systems, to the basic implementation of automatic differentiation tools, to the underlying device-level implementation of efficient algorithms. Throughout the course, students will design and build from scratch a complete deep learning library, capable of efficient GPU-based operations, automatic differentiation of all implemented functions, and the necessary modules to support parameterized layers, loss functions, data loaders, and optimizers. Using these tools, students will then build several state-of-the-art modeling methods, including convolutional networks for image classification and segmentation, recurrent networks and self-attention models for sequential tasks such as language modeling, and generative models for image generation.
Prerequisites: (15-513 Min. grade C or 15-213 Min. grade C) and (21-240 Min. grade C or 21-241 Min. grade C) and (21-128 Min. grade C or 21-127 Min. grade C or 15-151 Min. grade C) and (10-315 Min. grade C or 10-601 Min. grade C or 10-701 Min. grade C or 10-715 Min. grade C or 10-301 Min. grade C)

10-715 Advanced Introduction to Machine Learning

Fall: 12 units
Machine Learning is the primary pillar that Artificial Intelligence is built upon. This course is designed for Ph.D. students whose primary field of study is machine learning, and who intend to make machine learning methodological research a main focus of their thesis. It will give students a thorough grounding in the algorithms, mathematics, theories, and insights needed to do in-depth research and applications in machine learning. The topics of this course will in part parallel those covered in the general PhD-level machine learning course (10-701), but with a greater emphasis on depth in theory. Students entering the class are expected to have a pre-existing strong working knowledge of linear algebra, probability, statistics, and algorithms. The course will also involve programming in Python. If you are interested in this topic, but do not have the required background or are not planning to work on a PhD thesis with machine learning as the main focus, you might consider the general PhD-level Machine Learning course (10-701) or the Masters-level Machine Learning course (10-601). You can find a webpage to the Intro to ML course comparison page, which includes a self-assessment exam to help you choose which Intro to ML course to take, in the Course URL field.
Prerequisites: 15-122 Min. grade C and (15-151 Min. grade C or 21-127 Min. grade C or 21-128 Min. grade C) and (15-359 Min. grade C or 36-225 Min. grade C or 36-217 Min. grade C or 21-325 Min. grade C or 15-259 Min. grade C or 36-218 Min. grade C)

Course Website: https://www.cs.cmu.edu/~nihars/teaching/10715-Fa23/index.html (https://www.cs.cmu.edu/~nihars/teaching/10715-Fa23/)

10-716 Advanced Machine Learning: Theory and Methods

Spring: 12 units
Advanced Machine Learning is a graduate level course introducing the theoretical foundations of modern machine learning, as well as advanced methods and frameworks used in modern machine learning. The course assumes that students have taken graduate level introductory courses in machine learning (Introduction to Machine Learning, 10-701 or 10-715), as well as Statistics (Intermediate Statistics, 36-700 or 36-705). The course treats both the art of designing good learning algorithms, as well as the science of analyzing an algorithm's computational and statistical properties and performance guarantees. Theorems are presented together with practical aspects of methodology and intuition to help students develop tools for selecting appropriate methods and approaches to problems in their own research. We will cover advanced machine learning methods such as nonparametric and deep compositional approaches to density estimation and regression; advanced theory such as fundamentals of clustering, classification, boosting; theory and methods at the intersection of statistical and computational efficiency; as well as vignettes of theoretical results on some hot topics such as robustness and explainability.
Prerequisites: (10-701 Min. grade C or 10-715 Min. grade C) and (36-705 Min. grade C or 36-700 Min. grade C)

Course Website: http://www.cs.cmu.edu/~pradeepr/716/

10-725 Convex Optimization

Intermittent: 12 units
Nearly every problem in machine learning can be formulated as the optimization of some function, possibly under some set of constraints. This universal reduction may seem to suggest that such optimization tasks are intractable. Fortunately, many real world problems have special structure, such as convexity, smoothness, separability, etc., which allow us to formulate optimization problems that can often be solved efficiently. This course is designed to give a graduate-level student a thorough grounding in the formulation of optimization problems that exploit such structure, and in efficient solution methods for these problems. The main focus is on the formulation and solution of convex optimization problems, though we will discuss some recent advances in nonconvex optimization. These general concepts will also be illustrated through applications in machine learning and statistics. Students entering the class should have a pre-existing working knowledge of algorithms, though the class has been designed to allow students with a strong numerate background to catch up and fully participate. Though not required, having taken 10-701 or an equivalent machine learning or statistical modeling class is strongly encouraged, as we will use applications in machine learning and statistics to demonstrate the concepts we cover in class. Students will work on an extensive optimization-based project throughout the semester.
Prerequisites: (21-240 Min. grade C or 10-606 Min. grade C or 21-671 Min. grade C or 21-242 Min. grade C or 21-341 Min. grade C) and (21-254 Min. grade C or 21-259 Min. grade C or 21-268 Min. grade C) and (15-259 Min. grade C or 36-218 Min. grade C or 36-219 Min. grade C or 36-225 Min. grade C or 21-325 Min. grade C or 15-359 Min. grade C or 36-217 Min. grade C)

Course Website: https://sites.google.com/view/convexopt-10725-2023f (https://sites.google.com/view/convexopt-10725-2023f/)

10-735 Responsible AI

Intermittent: 12 units
The development and deployment of artificial intelligence (AI) systems increasingly involves choices that impact people's lives and society at large. The responsible development and use of AI requires the integration of ethical, societal, and policy considerations into the use of AI tools and the development of AI systems in high-stakes domains, such as employment, education, lending, criminal justice, medicine, and beyond. We will discuss: (1) the pathways through which AI can lead to or amplify problematic decision-making practices (e.g., discrimination, inscrutability, invasion of privacy, and beyond); (2) recent technological methods and remedies to capture and alleviate these concerns; and (3) the scope of applicability and limitations of technological remedies in the context of several contemporary application domains. The course's primary goals are: (a) to raise awareness about the social, ethical, and policy implications of AI, and (b) to prepare students to critically analyze these issues as they emerge in the ever-expanding use of AI in socially consequential domains.
Prerequisites: 15-122 Min. grade C and (21-127 Min. grade C or 15-151 Min. grade C or 21-128 Min. grade C) and (36-217 Min. grade C or 21-325 Min. grade C or 36-218 Min. grade C or 36-219 Min. grade C or 15-259 Min. grade C or 36-235 Min. grade C or 36-225 Min. grade C or 15-359 Min. grade C)

Course Website: https://www.cs.cmu.edu/~hheidari/rai-spring-24.html

10-737 Creative AI

Intermittent
Artificial intelligence (AI) systems now generate authentic paintings, compose music pieces, and find out-of-box solutions to real-life problems in our world. Creativity, which was considered to be a moon shot for AI, does not seem to be too far any more. Is that true? Are we close to see creative AI? The answer is yes and no. We are moving closer with meaningful developments in Machine Learning, however there are several questions to be explored further to achieve the creative AI. What kind of creativity we want to represent? How do we translate creativity into what machines can understand? How do we design ML algorithms to be more creative? This course is where we explore these questions through seminars and projects. Our goal is to design computational models that present the very possibility of the creative AI. The instructors who are specialized in Machine Learning Art and Robotics lead this course together. We introduce related examples and possible methods including multi-modal data-driven learning, learning from demonstration, and combined learning from data and human demonstrations. Students are welcome to bring in their expertise and passion from diverse backgrounds to explore this topic together.

Course Website: http://kangeunsu.com/creativeai19f/

10-745 Scalability in Machine Learning

Fall: 12 units
The goal of this course is to provide a survey into some of the recent advances in the theory and practice of dealing with scalability issues in machine learning. We will investigate scalability issues along the following dimensions: Challenges with i) large datasets, ii) high-dimensions, and iii) complex data structure. The course is intended to prepare students to write research papers about scalability issues in machine learning. This is an advanced-level, fast-paced course that requires students to already have a solid understanding of machine learning (e.g. by taking an intro to ML class), good programming skills in Python, and being comfortable with dealing with abstract mathematical concepts and reading research papers. The course will have significant overlap with 10-405/605/805, but 10-745 will be faster-paced and go deeper into the theoretical investigations of the methods. Some of the classes will be flipped that will require students to watch a video lecture or read a research paper before the class, and the content will be discussed during the class time. The class will include a course project, HW assignments, and two-in class exams.
Prerequisites: 10-601 Min. grade B or 10-315 Min. grade B or 10-701 Min. grade B or 10-401 Min. grade B or 10-301 Min. grade B or 10-715 Min. grade B

10-777 Historical Advances in Machine Learning

Intermittent: 12 units
We will read (before class) and discuss (in class) a variety of historically important papers in ML (and to some extent AI). Not all of these were initially published in the ML/AI literature (eg: Bellman in math, VC in probability, bandits in statistics, fuzzy sets in control, optimization work in OR, etc, but now play central roles in ML and/or AI). Since "historical" is always ambiguous, we're going to go with "presented/published before the instructor was born" as a definition (pre-1988). While the content of the paper will be the primary focus, we will also attempt to understand the research context in which the paper was written. For example, what questions were other researchers asking at the time? Was the paper immediately recognized as a breakthrough or did it take a long time? Do we view the contents of the paper today as "obvious in hindsight" or is there still a lot of material in the paper that is nontrivial and even surprising or underappreciated? Who was the author, were they already relatively well known when they wrote the paper, or was it the paper itself that made them famous? What else did these authors work on before/after the paper?
Prerequisites: 10-601 Min. grade C or 10-701 Min. grade C or 10-715 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C

10-805 Machine Learning with Large Datasets

Spring: 12 units
Large datasets pose difficulties across the machine learning pipeline. They are difficult to visualize and introduce computational, storage, and communication bottlenecks during data preprocessing and model training. Moreover, high capacity models often used in conjunction with large datasets introduce additional computational and storage hurdles during model training and inference. This course is intended to provide a student with the mathematical, algorithmic, and practical knowledge of issues involving learning with large datasets. Among the topics considered are: data cleaning, visualization, and pre-processing at scale; principles of parallel and distributed computing for machine learning; techniques for scalable deep learning; analysis of programs in terms of memory, computation, and (for parallel methods) communication complexity; and methods for low-latency inference. The class will include programming and written assignments to provide hands-on experience applying machine learning at scale. An introductory machine learning course (10-301, 10-315, 10-601, 10-701, or 10-715) is a prerequisite. A strong background in programming will also be necessary; suggested prerequisites include 15-210, 15-214, or equivalent. Students are expected to be familiar with Python or learn it during the course.
Prerequisites: (17-214 or 15-211 or 15-210 or 15-214) and (10-301 or 10-315 or 10-701 or 10-401 or 10-601 or 10-715)

Course Website: https://10605.github.io/

10-806 Foundations of Machine Learning and Data Science

Fall: 12 units
This course will cover fundamental topics in Machine Learning and Data Science, including powerful algorithms with provable guarantees for making sense of and generalizing from large amounts of data. The course will start by providing a basic arsenal of useful statistical and computational tools, including generalization guarantees, core algorithmic methods, and fundamental analysis models. We will examine questions such as: Under what conditions can we hope to meaningfully generalize from limited data? How can we best combine different kinds of information such as labeled and unlabeled data, leverage multiple related learning tasks, or leverage multiple types of features? What can we prove about methods for summarizing and making sense of massive datasets, especially under limited memory? We will also examine other important constraints and resources in data science including privacy, communication, and taking advantage of limited interaction. In addressing these and related questions we will make connections to statistics, algorithms, linear algebra, complexity theory, information theory, optimization, game theory, and empirical machine learning research. Topics to be covered will include:
- Fundamental measures of complexity for generalization, including VC-dimension and Rademacher complexity. - Core algorithmic tools including boosting, regularization, and online optimization with connections to game theory. - Spectral methods, streaming algorithms and other approaches for handling massive data. - Foundations and algorithms for addressing important constraints or externalities such as privacy, limited memory, and communication constraints. - Foundations for modern learning paradigms including semi-supervised learning, never-ending learning, interactive learning, and deep learning.

Course Website: http://www.cs.cmu.edu/~ninamf/courses/806/10-806-index.html (http://www.cs.cmu.edu/~ninamf/courses/806/10-806-)

10-807 Topics in Deep Learning

Fall: 12 units
Building intelligent machines that are capable of extracting meaningful representations from high-dimensional data lies at the core of solving many AI related tasks. In the past few years, researchers across many different communities, from applied statistics to engineering, computer science and neuroscience, have developed deep (hierarchical) models and #8212; models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. This is an advanced graduate course, designed for Master's and Ph.D. level students, and will assume a reasonable degree of mathematical maturity. The goal of this course is to introduce students to the recent and exciting developments of various deep learning methods. Some topics to be covered include: restricted Boltzmann machines (RBMs) and their multi-layer extensions Deep Belief Networks and Deep Boltzmann machines; sparse coding, autoencoders, variational autoencoders, convolutional neural networks, recurrent neural networks, generative adversarial networks, and attention-based models with applications in vision, NLP, and multimodal learning. We will also address mathematical issues, focusing on efficient large-scale optimization methods for inference and learning, as well as training density models with intractable partition functions. Prerequisite: ML: 10-701 or 10-715, and strong programming skills.
Prerequisites: 10-715 Min. grade C or 10-701 Min. grade C

10-822 Presentation Skills

Fall and Spring: 6 units
This course provides a forum for students to learn and refine public speaking and technical reading skills. The course will include brief workshops embedded throughout the semester to cover such things as effective structure of presentations and papers, how to give a short talk (think NIPS spotlights), "elevator" talks, structure of a research paper, conference presentations, proposal writing (think thesis and beyond), slide crafting, posters, critical evaluation, and public communications for research. Students will be expected to prepare and present a number of practice talks throughout the semester.

10-830 Machine Learning in Policy

Spring: 12 units
Machine learning, a field derived primarily from computer science and statistics, has matured and gained wide adoption over past decades. Alongside exponential increases in data measurement and availability, the ability to develop appropriate and tailored analyses is in demand. As practitioners in the social sciences consider machine learning methods, however, we are identifying limitations and externalities of the applications of machine learning techniques, such as overconfidence in settings with concept drift, lack of generalizability due to selection bias, and magnification of inequities. Machine Learning and Policy seeks to (1) demonstrate motivations and successes of machine learning, to (2) contrast them with more classical methods, and to (3) investigate the promise and cautions of machine learning for public policy. The course will cover variety of topics, including: Basics of machine learning; probability/Bayes/likelihood/conjugacy, terminology, code/algorithm design, evaluation, mathematical formulations Popular and well-performing methods; random forests/trees/ensembles, neural networks/backpropagation/embeddings/generalized adversarial networks, generalized linear models/shrinkage/convexity/basis functions, support vector machines/kernels/optimization/Lagrangian Leveraging other data sources; natural language processing/topic modeling/relational (non-i.i.d.)/relational (Markov logic networks)/temporal data Additional topics: causality/confounding/propensity scoring/inverse weighting/causal directed acyclic graphs, fairness/ethics, interpretation/explanation/visualization, anomaly detection, semi-supervised and active learning, reinforcement learning.

Course Website: https://www.andrew.cmu.edu/user/jweiss2/mlp/

10-831 Special Topics in Machine Learning and Policy

Spring: 6 units
Special Topics in Machine Learning and Policy (90-921/10-831) is intended for Ph.D. students in Heinz College, MLD, and other university departments who wish to engage in detailed exploration of a specific topic at the intersection of machine learning and public policy. Qualified master's students may also enroll with permission of the instructor; all students are expected to have some prior background in machine learning and data mining (10-601, 10-701, 90-866, 90-904/10-830, or a similar course). We will explore state-of-the-art methods for detection of emerging events and other relevant patterns in massive, high-dimensional datasets, and discuss how such methods can be applied usefully for the public good in medicine, public health, law enforcement, security, and other domains. The course will consist of lectures, discussions on current research articles and future directions, and course projects. Specific topics to be covered may include: anomaly detection, change-point detection, time series monitoring, spatial and space-time scan statistics, pattern detection in graph data, submodularity and LTSS properties for efficient pattern detection, combining multiple data sources, scaling up pattern detection to massive datasets, applications to public health, law enforcement, homeland security, and health care. A sample syllabus is available at: http://www.cs.cmu.edu/~neill/courses/90921-S10.html
Course Website: http://www.cs.cmu.edu/~neill/courses/90921-S10.html

Robotics Courses

16-161 ROB Seminar: Artificial Intelligence and Humanity

Fall and Spring: 12 units
In 1965 British mathematician I.J. Good wrote, An ultraintelligent machine could design even better machines; there would then unquestionably be an intelligence explosion, and the intelligence of man would be left far behind. As we enter an age where companies like Uber are testing driverless cars in Pittsburgh and innovative interfaces like IBMs Watson can play jeopardy and learn techniques for medical diagnoses, how are we to negotiate an intelligence explosion that for many individuals might threaten the very notions of what it means to be human? The future of human-to-machine relationships will likely define our historical epoch and yet, many young technologists and humanists underestimate the downstream impact of technological innovations on human society. Presently, we have little choice but to attend to this rapidly anxiety-ridden question. This seminar will attend to the challenge of present existential questions on what it means to be human (read not machine) in the context of a rapidly advancing technological age. We will consider human narratives throughout history that exam how governments and individual citizens defined humanity in the context of slavery and colonialism as a framework for exploring and projecting what it means to be human in the age of rapidly advancing intelligent machines. We will trace the technological advancements of the recent five decades and identify historical precedents and speculative narratives that help us to consider issues like labor, economic disparity, negotiations of power, human dignity and ethical responsibility within the context of human relations with advancing technological tools that are now coined, artificial intelligence.

16-170 Concepts of Robotics

Spring: 5 units
The course will introduce students to the main foundational concepts and techniques used in robotics including perception, cognition, and action. Concepts will be grounded in a range of real-world robotic systems to highlight the use of common robotics components such as sensor selection, sensor processing and fusion, path planning algorithms, mechanism design, reasoning about interactions with the environment, and systems integration. Applications of robotics will be discussed along with methods for mapping application requirements to design choices for robotic systems. Students will also be introduced to ethical issues surrounding robotics, including considerations around potential future of uses of robotics technologies. The course will contain programming and written assignments designed to give students a feel for the practical aspects of robot sensing, planning, and actuation.
Prerequisite: 15-112 Min. grade C

16-211 Foundational Mathematics of Robotics

Fall: 12 units
This course will cover core mathematics concepts used in many advanced robotics courses at the RI. Perhaps unlike prior courses in math, the focus of this class will be to ground concepts in robotics algorithms or applications. For example: How to move and manipulate objects in 3D space (coordinate transforms, rotations). How to move an articulated robots end-effector in Cartesian space (Jacobians, gradient optimization). How to have a robot learn to recognize a vision input (neural networks, back propagation). How to plan navigate a robot optimally (dynamic programming, A* Search).
Prerequisites: 21-122 and 21-241

16-220 Robot Building Practices

Fall: 12 units
This course is designed to provide students with a comprehensive set of mechanical and electronics skills required for designing, prototyping, building, and troubleshooting robotic systems. Students will learn about basic robotic components and how to obtain, build, or fix them to create functional robotic systems. The course will cover mechanical skills specific to robotics, including sketching, 3D CAD modeling, 3D printing, laser cutting and other machine shop tools. Students will also learn the fundamentals of circuit design, breadboarding, and PCB layout using CAD tools, as well as how to use measurement equipment and soldering techniques. They will gain hands-on experience with motor controllers and microcontrollers, essential components for controlling robots. The class project will give students the opportunity to learn how to design and implement power transmission systems and prototype mechanical components required in building a functional robotic module and later a full robotic system. The course will include robot-specific topics such as kinematics, robot actuators, sensors, and perception algorithms. Upon completion of this course, students will have a solid foundation in electronics and mechanical prototyping for robotics and be able to create innovative robots for a variety of applications.
Prerequisite: 15-122 Min. grade C

16-223 IDeATe Portal: Creative Kinetic Systems

Fall: 10 units
The art and science of machines which evoke human delight through physical movement is founded on a balance of form and computation. This introductory physical computing course addresses the practical design and fabrication of robots, interactive gadgets, and kinetic sculptures. The emphasis is on creating experiences for human audiences through the physical behavior of devices which embody computation with mechanism, sensing, and actuation. Specific topics include basic electronics, elementary mechanical design, embedded programming, and parametric CAD. A key objective is gaining an intuitive understanding of how information and energy move between the physical, electronic, and computational domains to create a compelling behavior. The final projects are tested in the field on children and adults. This interdisciplinary course is an IDeATe Portal Course open to students from all colleges. For students choosing to follow an IDeATe program it is an entry into either Physical Computing or Intelligent Environments. The structure of the class revolves around collaborative exercises and projects which introduce core physical computing and system engineering techniques in a human-centric context. Students apply system and design thinking across multiple domains, work together to make and test several devices, and participate in wide-ranging critique which considers both technical and artistic success.

Course Website: https://courses.ideate.cmu.edu/16-223 (https://courses.ideate.cmu.edu/16-223/)

16-224 IDeATe: Re-Crafting Computational Thinking with Soft Technologies

Spring: 12 units
This course focuses on teaching introductory concepts of Robotics, Mechatronics, and Computer Science using an arts-based approach. During the course, students will build their own weaving robot, program it, and learn how weaving art is connected to computer programming and matrix mathematics. Students will also learn the history of weaving, how to design beautiful patterns, and how to extract the features of those patterns into mathematical equations and computer programs.

16-235 Fantastic Robots and How to Fold Them

Spring: 9 units
This course will focus on the basics of robotics through a hands-on approach. Students will build their own robots by designing a mechanical structure and embedding actuators, sensors, and controllers. They will then use these robots to solve a simple maze with obstacles. The course content will be delivered through lectures, workshops, and a course-long team project. In classical robotics, we explore the three main behaviors of robots through the work frame of "sense-plan-act". Robots are more than just these behaviors, and students will learn about how to make the physical embodiments of robots through an overview of design and manufacturing techniques for robot mechanisms. Students will be able to make their own mechanisms, improve the system through hardware or software, and learn how to analyze the kinematics and dynamics of these mechanisms to understand and control the motion.
Prerequisites: 15-110 Min. grade C or 15-112 Min. grade C or 15-104 Min. grade C

16-264 Humanoids

Spring: 12 units
This course surveys perception, cognition, and movement in humans, humanoid robots, and humanoid graphical characters. Application areas include more human-like robots, video game characters, and interactive movie characters.

Course Website: http://www.cs.cmu.edu/~cga/humanoids-ugrad/

16-299 Introduction to Feedback Control Systems

Spring: 12 units
This course is designed as a first course in feedback control systems for computer science majors. Course topics include classical linear control theory (differential equations, Laplace transforms, feedback control), linear state-space methods (controllability/observability, pole placement, LQR), nonlinear systems theory, and an introduction to control using computer learning techniques. Priorities will be given to computer science majors with a robotics major or minor.
Prerequisites: 21-122 and 15-122

Course Website: http://www.cs.cmu.edu/~cga/controls-intro/

16-311 Introduction to Robotics

Spring: 12 units
This course presents an overview of robotics in practice and research with topics including vision, machine learning, motion planning, mobile mechanisms, kinematics, inverse kinematics, and sensors. In course projects, students construct LEGO robots which are driven by a microcontroller, with each project reinforcing the basic principles developed in lectures. Students usually work in teams of three: an electrical engineer, a mechanical engineer, and a computer scientist. Groups are typically self-formed except for the first lab. This course will also expose students to some of the contemporary happenings in robotics, including current robotics research, applications, robot contests and robots in the news. Students registering for this course must register for both Mon/Wed mornings and Tuesday afternoon sections.
Prerequisites: 18-202 Min. grade C or 21-240 Min. grade C or 21-241 Min. grade C or 24-311 Min. grade C or 21-260 Min. grade C

Course Website: http://www.cs.cmu.edu/afs/cs.cmu.edu/academic/class/16311/www/current/

16-322 Modern Sensors for Intelligent Systems

Spring: 12 units
The class aims at introducing sensing technologies for robots and other intelligent systems. The course will cover the physical principles of traditional sensors, sensor calibration and evaluation, signal processing algorithms for different sensors, and examples of sensor applications for robots or other intelligent systems. On the sensing system design part, the course will cover the common sensor fusion design and algorithms, and provide examples of sensing systems for different robots or intelligent systems, such as wearable sensors, self-driving cars, autonomous vehicles, assistant robots, and field robots in extreme conditions. The class will contain lectures, two lab sessions, and a course project.

16-350 Planning Techniques for Robotics

Spring: 12 units
Planning is one of the core components that enable robots to be autonomous. Robot planning is responsible for deciding in real-time what should the robot do next, how to do it, where should the robot move next and how to move there. This class does an in-depth study of popular planning techniques in robotics and examines their use in ground and aerial robots, humanoids, mobile manipulation platforms and multi-robot systems. The students learn the theory of these methods and also implement them in a series of programming-based projects. To take the class students should have taken an Intro to Robotics class and have a good knowledge of programming and data structures.

Course Website: http://www.cs.cmu.edu/~maxim/classes/robotplanning/

16-362 Mobile Robot Algorithms Laboratory

Fall: 12 units
This course is an introduction to the theory and algorithms of multirotor vehicle autonomy. Students will work individually to develop a multirotor simulator in Python and C++, add sensors, plan, and perform exploration. Lectures will cover topics to advance the capabilities of the simulator. Homeworks will be designed to increase the autonomy capabilities of the multirotor vehicle. The class will culminate in an individual project that pushes the autonomy capabilities developed throughout the course and may cover multi-robot aerial autonomy, dynamic environment modeling, or advanced planning and control. In order to succeed in the course, students must have a 2nd year science/engineering level background in mathematics (matrices, vectors, coordinate systems) and have already mastered at least one object-oriented programming language like C++ or Python. When the course is over, students will have written a single software system that has been incrementally extended in functionality and regularly debugged throughout the semester.

16-371 Personalized Responsive Environments

Spring: 9 units
[IDeATe collaborative course]. Environmental factors have a significant impact on mood and productivity. Creating responsive environments necessitates the design of surroundings that are able to metamorphose in order to optimize user strengths and available resources and evolve in stride with user needs. This course will investigate the development of spaces that adapt to user preferences, moods, and task specific demands. Both the design and engineering of such personalized environments will be explored. Central course concepts will include, understanding the user, integrating various modalities (e.g., light, heat, sound) to support the changing needs of task and user, and the creation of adaptive environments that learn user preferences over time. Please note that there may be usage/materials fees associated with this course.
Prerequisites: 60-223 Min. grade C or 62-150 Min. grade C or 18-090 Min. grade C or 15-104 Min. grade C

16-374 IDeATe: Art of Robotic Special Effects

Spring: 12 units
Inspired by the early "trick" films of George Melies, this project-oriented course brings together robotics and film production technique to infuse cinema with the wonder of live magic. Students will learn the basics of film production using animatronics, camera motion control, and compositing. The projects apply these techniques to create innovative physical effects for short films, all the way from concept to post-production. The course emphasizes real-time practical effects to explore the immediacy and interactivity of improvisation and rehearsal. The robotics topics include animatronic rapid prototyping and programming human-robot collaborative performance. The course includes a brief overview of the history of special effects and robotics to set the work in context.

Course Website: https://courses.ideate.cmu.edu/16-374 (https://courses.ideate.cmu.edu/16-374/)

16-375 IDeATe: Robotics for Creative Practice

Fall: 10 units
Robots come in all shapes and sizes: it is the integration of software and hardware that can make any machine surprisingly animate. This project-oriented course brings art and engineering together to build performance systems using embodied behavior as a creative medium. Students learn skills for designing, constructing and programming automated systems for storytelling and human interaction, then explore the results through exhibition and performance. Technical topics include closed-loop motion control, expressive physical and computational behavior, machine choreography, and performance conceptualization. Discussion topics include both contemporary kinetic sculpture and robotics research. This interdisciplinary course is part of IDeATe Physical Computing but is open to any student.
Prerequisites: 15-110 or 15-104 or 15-112 or 99-361 or 60-212 or 60-210

Course Website: https://courses.ideate.cmu.edu/16-375 (https://courses.ideate.cmu.edu/16-375/)

16-376 IDeATe: Kinetic Fabrics

Spring: 10 units
Kinetic Fabrics brings together the fields of robotics and textiles to explore their unified creative and expressive potential. It is a wide-open frontier for kinetic art, wearable art, and architectural installation. In this course students will build a variety of performative systems combining fabrics and robotic technologies. Students will apply modular actuation and sensing to textile artworks, using software designed to facilitate fluid explorations, rapid iterations, and playful experimentation. Students will learn basic textile skills, such as hand and machine sewing, as well as gain facility and familiarity with the characteristics of multiple type of fabrics. Historical precedents as well as contemporary examples of works will support students creative growth and knowledge of the field. Students' course work will include short-term and long-term projects, sampling and prototyping, critique, and documentation. Additionally, students will organize an end-of-semester event where they will perform a developed kinetic fabric work for a public audience.

Course Website: https://courses.ideate.cmu.edu/16-376 (https://courses.ideate.cmu.edu/16-376/)

16-384 Robot Kinematics and Dynamics

Fall: 12 units
Foundations and principles of robotic kinematics. Topics include transformations, forward kinematics, inverse kinematics, differential kinematics (Jacobians), manipulability, and basic equations of motion. Course also include programming on robot arms.
Prerequisites: 15-122 Min. grade C or 16-311 or 18-202 or 21-241 or 24-311

16-385 Computer Vision

Fall and Spring: 12 units
This course provides a comprehensive introduction to computer vision. Major topics include image processing, detection and recognition, geometry-based and physics-based vision, sensing and perception, and video analysis. Students will learn basic concepts of computer vision as well as hands on experience to solve real-life vision problems. This course is for undergraduate students only.
Prerequisites: (18-202 Min. grade C and 15-122 Min. grade C) or (21-259 Min. grade C and 15-122 Min. grade C and 21-241 Min. grade C) or (21-241 Min. grade C and 21-256 Min. grade C and 15-122 Min. grade C) or (24-282 Min. grade C and 15-122 Min. grade C and 21-241 Min. grade C) or (21-254 Min. grade C and 15-122 Min. grade C and 21-241 Min. grade C)

Course Website: http://www.cs.cmu.edu/~16385/

16-397 Art, Conflict and Technology

Spring: 12 units
This course considers the period of violence in Northern Ireland from 1968 to 1998 known as The Troubles, and recent issues pertaining to sovereignty and borders caused by Brexit, Britain's proposed exit from the European Union, as a point of comparison between societies rife with strife, division and predilections to violence. We investigate the ways in which visual art to literature to theatrical performance explores and interrogates societal conflict and emergence from conflict, and how evolving technological systems influence political power dynamics and modes of artistic practice. We will use the legacy of societal conflict in Ireland and Northern Ireland to compare concepts and physical manifestations of borders, barriers and bridges in the region and in global contexts. We will examine fluctuating development of democratic processes in Ireland and Northern Ireland, individual and group public performance, and the influence of technologically crude and highly sophisticated tools on communities emerging from strife. We will use our analytical lens to focus on figurative and literal borders, barriers and bridges to explore work produced in Belfast, Derry and Dublin, alongside circumstances and artistic practice in present-day Pittsburgh, Cuidad Juarez, Jerusalem and Soweto. On a visit to Ireland and Northern Ireland over spring break, students will meet with artists, writers, legislators, community organizers, academics and ex-combatants, to learn about their past experience and current motivations. Students will analyze artistic practice, peacekeeping initiatives and performance of identity in relation to the historical framework from which it emerges in Ireland and Northern Ireland. We will use this foundation as a point of comparison to practices throughout the world. Students will process their experience and developing analytical skills by documenting their responses through original creative work.

16-421 Vision Sensors

Spring: 12 units
This course covers the fundamentals of vision cameras and other sensors - how they function, how they are built, and how to use them effectively. The course presents a journey through the fascinating five hundered year history of "camera-making" from the early 1500's "camera obscura" through the advent of film and lenses, to today's mirror-based and solid state devices (CCD, CMOS). The course includes a significant hands-on component where students learn how to use the sensors and understand, model and deal with the uncertainty (noise) in their measurements. While the first half of the course deals with conventional "single viewpoint" or "perspective" cameras, the second half of the course covers much more recent "multi-viewpoint" or "multi-perspective" cameras that includes a host of lenses and mirrors.
Prerequisites: 21-111 and 21-241

Course Website: http://www.cs.cmu.edu/~ILIM/courses/vision-sensors/

16-423 Designing Computer Vision Apps

Fall: 12 units
Computer vision is a discipline that attempts to extract information from images and videos. Nearly every smart device on the planet has a camera, and people are increasingly interested in how to develop apps that use computer vision to perform an ever expanding list of things including: 3D mapping, photo/image search, people/object tracking, augmented reality etc. This course is intended for students who are not familiar with computer vision, but want to come up to speed rapidly with the latest in environments, software tools and best practices for developing computer vision apps. No prior knowledge of computer vision or machine learning is required although a strong programming background is a must (at a minimum good knowledge of C/C++). Topics will include using conventional computer vision software tools (OpenCV, MATLAB toolboxes, VLFeat, CAFFE), and development on iOS devices using mobile vision libraries such as GPUImage and fast math libraries like Armadillo and Eigen. For consistency, all app development will be in iOS and it is expected that all students participating in the class have access to an Intel-based MAC running OS X Mavericks or later. Although the coursework will be focussed on a single operating system, the knowledge gained from this class is intended to generalize to other mobile platforms such as Android etc.
Prerequisites: (21-240 and 15-213) or (21-241 and 15-213) or (18-202 and 18-213)

Course Website: http://16423.courses.cs.cmu.edu

16-425 Medical Image Analysis

Spring: 12 units
Students will gain theoretical and practical skills in 2D, 3D, and 4D biomedical image analysis, including skills relevant to general image analysis. The fundamentals of computational medical image analysis will be explored, leading to current research in applying geometry and statistics to segmentation, registration, visualization, and image understanding. Additional and related covered topics include de-noising/restoration, morphology, level sets, and shape/feature analysis. Students will develop practical experience through projects using the latest version of the National Library of Medicine Insight Toolkit (ITK) and SimpleITK, a popular open-source software library developed by a consortium of institutions including Carnegie Mellon University and the University of Pittsburgh. In addition to image analysis, the course will include interaction with radiologists and pathologist(s). *** Lectures are at CMU and students will visit clinicians at UPMC. Some or all of the class lectures may also be videoed for public distribution, but students may request to be excluded from distributed video. 16-725 is a graduate class, and 16-425 is a cross-listed undergraduate section. 16-425 is new this year, and has substantially reduced requirements for the final project and for the larger homework assignments, nor does it require shadowing the clinicians. Prerequisites: Knowledge of vector calculus, basic probability, and either C++ or python, including basic command-line familiarity and how to pass arguments to your own command-line programs. Extensive expertise with C++ and templates is not necessary, but some students may find it helpful.

Course Website: http://www.cs.cmu.edu/~galeotti/methods_course/

16-441 Advanced CP/SIS: Urban Intervention

Fall and Spring: 12 units
This course introduces students to theories, practices, and communities for critical investigation of urban spaces and play within them. The course unfolds along two parallel trajectories: research (literature review, lectures, readings, demonstrations) and design (three iterated individualized projects and a fourth larger scale final project). The first half of the course will introduce students to a wide range of theories and techniques within urban intervention that draw from fluxus, the situationist international, activism and hacktivism, as well as public policy, philosophy, psychology and economics. Students will study theoretical and practical frameworks for artistic intervention into public urban spaces, while concurrently researching actual sites and communities within Pittsburgh for experimentation. Students are required to conceptualized projects on larger (urban) scales, and find ways to implement their projects safely and legally by pursuing the necessary administrative, social, technical, financial steps required to create meaningful interventions in public spaces. This class will specifically explore three media for urban intervention: Sound Outdoor video projection Robotics, Autonomy and Mobility in the way of remote control vehicles (e.g. cars, quad-copters, etc.). For each theme, students are required to produce one project that is iterated twice or more. The undergraduate (60441) and graduate (60741) sections of the course meet concurrently and follow the same syllabus and assignments. In addition to the coursework documented in the syllabus, Graduate level students are expected to write a research paper suitable for submission to a notable relevant academic conference. This process includes a rough draft, revisions and a completed and formatted paper ready for submission

16-450 Robotics Systems Engineering

Fall: 12 units
Systems engineering examines methods of specifying, designing, analyzing and testing complex systems. In this course, principles and processes of systems engineering are introduced and applied to the development of robotic devices. The focus is on robotic system engineered to perform complex behavior. Such systems embed computing elements, integrate sensors and actuators, operate in a reliable and robust fashion, and demand rigorous engineering from conception through production. The course is organized as a progression through the systems engineering process of conceptualization, specification, design, and prototyping with consideration of verification and validation. Students completing this course will engineer a robotic system through its compete design and initial prototype. The project concept and teams can continue into the Spring-semester (16-474 Robotics Capstone) for system refinement, testing and demonstration.
Prerequisites: 16-311 Min. grade B and (16-299 Min. grade B or 18-370 Min. grade B or 24-451 Min. grade B)

16-455 IDeATe: Human-Machine Virtuosity

Spring: 12 units
[IDeATe course] Human dexterous skill embodies a wealth of physical understanding which complements computer-based design and machine fabrication. This project-oriented course explores the duality between hand and machine through the practical development of innovative design and fabrication systems. These systems fluidly combine the expressivity and intuition of physical tools with the scalability and precision of the digital realm. Students will develop novel hybrid design and production workflows combining analog and digital processes to support the design and fabrication of their chosen projects. Specific skills covered include 3D modeling (CAD), 3D scanning, algorithmic geometric modeling, digital and robotic fabrication (additive and subtractive manufacturing), motion capture and computer based sensing, and human-robot interaction design. Areas of interest include architecture, art, and product design.

Course Website: https://courses.ideate.cmu.edu/16-455 (https://courses.ideate.cmu.edu/16-455/)

16-456 Reality Computing Studio

Fall: 12 units
[IDeATe collaborative course] Reality computing encompasses a constellation of technologies focused around capturing reality (laser scanning, photogrammetry), working with spatial data (CAD, physical modeling, simulation), and using data to interact with and influence the physical world (augmented / virtual reality, projector systems, 3d printing, robotics). Taught in collaboration with the school of architecture, this studio asks students to apply these technologies to real world problems such as residential design, sustainability, and infrastructure monitoring.

Course Website: http://ideate.cmu.edu/about-ideate/departments/robotics-institute/reality-computing/

16-457 Reality Computing II

Spring: 12 units
[IDeATe collaborative course] Reality computing encompasses a constellation of technologies focused around capturing reality (laser scanning, photogrammetry), working with spatial data (CAD, physical modeling, simulation), and using data to interact with and influence the physical world (augmented / virtual reality, projector systems, 3d printing, robotics). This iteration of the reality computing course will focus on "design realization": the translation from digital design to fully realized tangible artifact. Collaborating with the UDBS design studio, and within the context of a full-scale residential prototype, students will investigate how reality computing technologies can be used to accelerate and advance the process of design realization by using reality computing to understand existing homes, map design data into the real world, and highlight conflicts between design and reality. Topics of special focus within the course are residential design (John Folan) and augmented reality and robotics (Pyry Matikainen).

Course Website: http://ideate.cmu.edu/about-ideate/departments/robotics-institute/reality-computing/

16-461 Experimental Capture

Fall: 9 units
Performance capture is used in applications as varied as special effects in movies, animation, sports training, physical rehabilitation, and human-robot/human-computer interaction. This course will survey state-of-the-art techniques and emerging ideas, in the industry and in academia, to capture, model, and render human performances. The course will be a mix between lectures and discussion of recent progress in human motion capture and analysis. The course evaluation will be project-based, in which students will capture their own body and face motion, and build projects around the data they collect individually and as a group. We will cover: 1. Capture Techniques: We will describe and use various systems including motion capture, video-based capture, depth sensors, scanners, and eye-gaze trackers; 2. Modeling and Representation: We will cover classic and contemporary representations of face and body pose and motion, including statistical and physics-based techniques; 3. Rendering Applications: As new rendering paradigms emerge, new applications continue to develop. We will study recent progress in animation, synthesis, classification, and rehabilitation on new forms of displays. Please note that there may be usage/materials fees associated with this course.
Prerequisites: 60-422 or 15-365

16-465 Game Engine Programming

Spring: 10 units
This course is designed to help students understand, modify, and develop game engines. Game engines consist of reusable runtime and asset pipeline code. They provide game-relevant abstractions of low-level system services and libraries, making it easier to write bug-free games that work across multiple platforms. Game engines also handle artistic content, providing or integrating with authoring tools to ease the process of creating high-fidelity games. In this course, we will discuss the problems game engines attempt to solve, examine how current state-of-the-art engines address these problems, and create our own engines based on what we learn. We will cover both the content authoring and runtime aspects of engines. Coursework will consist of frequent, tightly-scoped programming and system design assignments; expeditions through game engine source code; and two group projects and #8212; one in an engine created from scratch, and one that requires modification of an existing engine. Prerequisites: Students will be expected to be fluent in at least one programming language. We will be working with C++, Javascript, and a smattering of Python. We will be using git for version control and code sharing. The assignments in the course will be designed to be completed on an OSX or Linux workstation (e.g. the IDeATe "virtual cluster"). Working with Windows will be possible, but might require extra effort. We will be building a 3D model pipeline around Blender, but no prior knowledge of the tool will be assumed.
Prerequisites: 62-150 Min. grade C or 15-213 Min. grade C or 15-104 Min. grade C or 15-112 Min. grade C

16-467 Introduction to Human Robot Interaction

Spring: 12 units
The field of human-robot interaction (HRI) is fast becoming a significant area of research in robotics. The basic objective is to create natural and effective interactions between people and robots. HRI is highly interdisciplinary, bringing together methodologies and techniques from robotics, artificial intelligence, human-computer interaction, psychology, education, and other fields. This course is primarily lecture-based, with in-class participatory mini-projects, homework assignments, a group term project that will enable students to put theory to practice, and a final. The topics covered will include technologies that enable human-robot interactions, the psychology of interaction between people and robots, how to design and conduct HRI studies, and real-world applications such as assistive robots. This course has no prerequisites, but some basic familiarity with robots is recommended (programming knowledge is not necessary, but is useful for the term project).

Course Website: http://harp.ri.cmu.edu/courses (http://harp.ri.cmu.edu/courses/)

16-469 Innovation and Shared Prosperity: Community-engagement for change

Fall: 12 units
How might we, as a community of learners, utilize our collective talents for innovation and shift our society towards greater justice? In this course we will cover the historical and social context of university-community engagement, discuss best practices in engagement efforts, and operationalize emergent strategy alongside design justice principles. Learnings from this course will foster the growth of lifelong dispositions and habits that can empower learners to chart a course for their personal careers that are consonant with community empowerment and societal equity. This class is for individuals interested in pursuing a career at the intersection of technology and societal equity or for individuals who are interested in issues of justice and equity more broadly. Learning methods for this course will include readings, reflections, and in-class discussions. Students in this class will be asked to draw on their own experiences and to explore case studies. We also anticipate that students will directly engage with local community as facilitated through existing connections with the Center for Shared Prosperity.

16-474 Robotics Capstone

Spring: 12 units
In this course students refine the design of, build, integrate, test, and demonstrate the robot they designed in the prerequisite Systems Engineering course (16-450). The students are expected to continue to apply the process and methods of systems engineering to track requirements, evaluate alternatives, refine the cyberphysical architectures, plan and devise tests, verify the design, and validate system performance. The course consists of lectures, class meetings, reviews, and a final demonstration. Lectures cover special topics in project management. During class meetings the students and instructor review progress on the project and discuss technical and project-execution challenges. There are three major reviews, approximately at the end of each of the first three months of the semester. For each review, students give a presentation and submit an updated version of the System Design and Development Document. The course culminates in a System Performance Validation Demonstration at the end of the semester. Students also hold a special demonstration of their robotic system for the broader Robotics community.
Prerequisite: 16-450 Min. grade C

16-480 IDeATe: Creative Soft Robotics

Spring: 10 units
This experimental course offers unique topics situated at the intersection of robotics research and the arts, with a specific research focus that varies each semester. In this course, students survey the state of an emerging research area, then design and fabricate experimental systems and artworks on the theme. Students are guided through literature search and technical paper analysis to identify opportunities and techniques. The textual study spans contemporary robotics and arts literature. The project component is research-focused and explores novel techniques in design, fabrication, programming, and control. The project sequence culminates in the collaborative design of expressive robotic systems which match technical innovation with a human need or artistic expression. The initial iteration of the course focuses on soft robotics, an emerging discipline centered on devices constructed from compliant materials that incorporate sensing and actuation. The literature survey spans soft robotics and kinetic sculpture. The projects center on fabricating forms that incorporate actuators and sensors using silicone rubber cast into 3D-printed and laser-cut molds. This course is offered by IDeATe and this iteration will satisfy minor requirements for IDeATe Soft Technologies or IDeATe Physical Computing.

Course Website: https://courses.ideate.cmu.edu/16-480 (https://courses.ideate.cmu.edu/16-480/)

16-595 Undergraduate Independent Study

All Semesters
For students to pursue an independent study with a Robotics Institute faculty member.

16-597 Undergraduate Reading and Research

All Semesters
Undergraduate Reading and Research enables students to gain academic credits for conducing independent studies in robotics. Students must work with a robotics faculty advisor to devise a specific objective, activities (such as reading, evaluating, designing, coding, building, or testing robotic systems) and metrics for evaluation of their performance by their advisor.

16-621 MSCV Project I

Spring: 12 units
The MSCV capstone project course is designed to give project teams additional feedback on their capstone project from peers and faculty. Every week, capstone teams will present their project PPFs (Past-Present-Future) reports. For the presenting teams, the capstone course will help develop presentation and communication skills. For the students participating as peer-reviewers, it will help develop critical thinking and the ability to give constructive advice.

Course Website: https://piazza.com/cmu/spring2019/16621 (https://piazza.com/cmu/spring2019/16621/)

16-622 MSCV Capstone

Fall: 12 units
The MSCV capstone project course is designed to give project teams additional feedback on their capstone project from peers and faculty. Every week, capstone teams will present their project PPFs (Past-Present-Future) reports. For the presenting teams, the capstone course will help develop presentation and communication skills. For the students participating as peer-reviewers, it will help develop critical thinking and the ability to give constructive advice.

16-623 Advanced Computer Vision Apps.

Fall: 12 units
Computer vision is a discipline that attempts to extract information from images and videos. Nearly every smart device on the planet has a camera, and people are increasingly interested in how to develop apps that use computer vision to perform an ever expanding list of things including: 3D mapping, photo/image search, people/object tracking, augmented reality etc. This course is intended for graduate students who are familiar with computer vision, and are keen to learn more about the applying state of the art vision methods on smart devices and embedded systems. A strong programming background is a must (at a minimum good knowledge of C/C++), topics will include using conventional computer vision software tools (OpenCV, MATLAB toolboxes, VLFeat, CAFFE, Torch 7), and development on iOS devices using mobile vision libraries such as GPUImage, Metal and fast math libraries like Armadillo and Eigen. For consistency, all app development will be in iOS and it is expected that all students participating in the class have access to an Intel-based MAC running OS X Mavericks or later. Although the coursework will be focused on a single operating system, the knowledge gained from this class will easily generalize to other mobile platforms such as Android etc.
Prerequisites: 16-385 or 16-720

Course Website: http://16623.courses.cs.cmu.edu

16-627 MSCV Seminar

Fall
(Only open to MSCV students.) MSCV students will be required to participate in this one-semester seminar course which will prepare them for the MSCV project starting in the Spring semester. The first part of this course will cover talks by computer vision and related faculty about the ongoing research, development programs related to Computer Vision at CMU. The second part of this course will include student/faculty tutorial on topics such as OpenCV, Dataset Creation, Mechanical Turk etc. The goal of this series is to get students acquainted with practical knowledge for a successful project. In the last month of the course, each lecture will cover upto four possible MSCV projects pitched by faculty or industrial sponsors. At the end of the course students will turn in their choices, and a faculty committee will assign them the final projects.

16-633 Special Topic: Robot Cognition and Learning

Spring: 12 units
This is open to both Grad and Undergrad students. This project class focuses on developing cognitive and learning systems for robots. Students will become familiar with and use state of the art software tools to build prototype systems, as well as how to evaluate these systems. The course project will involve implementing a cognitive/learning system on a real robot. For undergraduates, this course is an elective for the Robotics Major.

Course Website: https://www.cs.cmu.edu/~cga/cog/

16-639 Special Topic: Scalable Robotic Systems: Infrastructure Development/Deployment

Spring: 12 units
As robots continue to permeate various sectors such as healthcare, manufacturing, and autonomous transportation, the ability to build and scale robust robotic systems has become increasingly crucial. This course aims to bridge the gap between single-robot deployments and large-scale robotic systems, providing students with a comprehensive understanding of the processes and tools necessary to scale their robotic projects.

16-663 F1Tenth Autonomous Racing

Spring: 12 units
This hands-on, lab-centered course is for senior undergraduates and graduate students interested in the fields of artificial perception, motion planning, control theory, and applied machine learning. It is also for studentsinterested in the burgeoning field of autonomous driving. This course introduces the students to the hardware, software and algorithms involved in building and racing an autonomous race car. Every week, students take two lectures and complete an extensive hands-on lab. By Week 6, the students will have built, programmed and driven a 1/10th scale autonomous race car. By Week 10, the students will have learned fundamental principles in perception, planning and control and will race using map-based approaches. In the last 6 weeks, they develop and implement advanced racing strategies, computer vision and machine learning algorithms that will give their team the edge in the race that concludes the course.

16-664 Self-Driving Cars: Perception & Control

Fall: 12 units
This course will teach the theoretical underpinnings of self-driving car algorithms and the practical application of the material in hands-on labs. Topics will include deep learning, computer vision, sensor fusion, localization, trajectory optimization, obstacle avoidance, and vehicle dynamics.

16-665 Robot Mobility on Air, Land, & Sea

Fall: 12 units
Required core course for MRSD first-year students. Many robots are designed to move through their environments. Three prevalent environments on earth are land, air, and water. This course will explore the modeling, control, and navigation of ground-based (wheeled and legged), air-based (rotorcraft such as quadcopters), and water-based robots.

16-667 Autonomous Air Vehicle Design and Development

All Semesters: 12 units
OPEN TO GRADUATE AND UNDERGRADUATE STUDENTS; Autonomous Air Vehicles are finding new applications in Civil Air Transportation and Emergency Response scenarios. They carry passengers and valuable supplies and must be certified to operate in both urban and rural areas, close to people, buildings, highways, mountains, and dense forest canopies. This presents significant challenges to perception, control systems, and navigation through austere environments. The design limits and flight operations of the aircraft must be understood to be certified by the FAA.
In Autonomous Air Vehicle Development, students will design, develop, and test prototype autonomous aircraft for specific missions defined by the new HeroX GoAero Challenge. This multidisciplinary course will go from concept to test and challenge students to apply sound theoretic approaches to a practical design. Students will learn how to design and build resilient autonomous air vehicle systems and the challenges of real-world design, operations, certification, and testing.

Course Website: https://www.herox.com/goaero (https://www.herox.com/goaero/)

16-675 Manufacturing Futures

Spring: 12 units
The course will introduce an array of technologies that will contribute to the future of making things and will be organized into 4 logical modules that will culminate in a team-based design project. Module 1 (Manufacturing Visions and Design Methodolgy): David Bourne. Module 2 (Manufacturing Processes and Process Tradeoffs): Brandon Bodily. Module 3 (Electronic Manufacturing): Rahul Panat. Module 4 (Workforce Development) : David Bourne.

16-682 Robotic Systems Development Project Course II

Fall: 15 units
Required core course for MRSD second-year students. This course is the second semester in a two-semester sequence intended to enable student teams to design and implement robot systems from the requirements development phase through implementation, verification, and demonstration of a working prototype. Teams of 4-5 students continue work on a project provided by industrial and academic partners, refine design requirements, refine or create new subsystems, and integrate and demonstrate the full system.

16-714 Advanced Control for Robotics

Fall: 12 units
This course will discuss advanced control algorithms that can make robots behave more intelligently. This course is directed to studentsprimarily graduate although talented undergraduates are welcome as wellinterested in advanced control.
Prerequisite: 16-711 Min. grade C

16-715 Advanced Robot Dynamics and Simulation

Fall: 12 units
This course explores the fundamental mathematics behind modeling the physics of robots, as well as state-of-the-art algorithms for robot simulation. We will review classical topics like Lagrangian mechanics and Hamilton's Principle of Least Action, as well as modern computational methods like discrete mechanics and fast linear-time algorithms for dynamics simulation. A particular focus of the course will be rigorous treatments of 3D rotations and non-smooth contact interactions (impacts and friction) that are so prevalent in robotics applications. We will use numerous case studies to explore these topics, including quadrotors, fixed-wing aircraft, wheeled vehicles, quadrupeds, humanoids, and manipulators. Homework assignments will focus on practical implementation of algorithms and a course project will encourage students to apply simulation methods to their own research.

16-720 Computer Vision

Fall and Spring: 12 units
Section A is a required core course for MRSD first-year students, and Section B is a required core course for MSCV students. This course introduces the fundamental techniques used in computer vision, that is, the analysis of patterns in visual images to reconstruct and understand the objects and scenes that generated them. Topics covered include image formation and representation, camera geometry, and calibration, computational imaging, multi-view geometry, stereo, 3D reconstruction from images, motion analysis, physics-based vision, image segmentation and object recognition. The material is based on graduate-level texts augmented with research papers, as appropriate. Evaluation is based on homeworks and a final project. The homeworks involve considerable Python programming exercises. Texts recommended but not required: Title: "Computer Vision Algorithms and Applications" Author: Richard Szeliski Series: Texts in Computer Science Publisher: Springer ISBN: 978-1-84882-934-3 Title: "Computer Vision: A Modern Approach" Authors: David Forsyth and Jean Ponce Publisher: Prentice Hall ISBN: 0-13-085198-1

Course Website: http://www.andrew.cmu.edu/course/16-720/

16-725 (Bio)Medical Image Analysis

Spring: 12 units
Students will gain theoretical and practical skills in 2D, 3D, and 4D biomedical image analysis, including skills relevant to general image analysis. The fundamentals of computational medical image analysis will be explored, leading to current research in applying geometry and statistics to segmentation, registration, visualization, and image understanding. Additional and related covered topics include de-noising/restoration, morphology, level sets, and shape/feature analysis. Students will develop practical experience through projects using the latest version of the National Library of Medicine Insight Toolkit (ITK) and SimpleITK, a popular open-source software library developed by a consortium of institutions including Carnegie Mellon University and the University of Pittsburgh.
In addition to image analysis, the course will include interaction with radiologists and pathologist(s). *** Lectures are at CMU and students will visit clinicians at UPMC. Some or all of the class lectures may also be videoed for public distribution, but students may request to be excluded from distributed video. 16-725 is a graduate class, and 16-425 is a cross-listed undergraduate section. 16-425 is new this year, and has substantially reduced requirements for the final project and for the larger homework assignments, nor does it require shadowing the clinicians. Prerequisites: Knowledge of vector calculus, basic probability, and either C++ or python, including basic command-line familiarity and how to pass arguments to your own command-line programs. Extensive expertise with C++ and templates is not necessary, but some students may find it helpful.

Course Website: http://www.cs.cmu.edu/~galeotti/methods_course/

16-726 Learning-based Image Synthesis

Spring: 12 units
This course introduces machine learning methods for image and video synthesis. The objectives of synthesis research vary from modeling statistical distributions of visual data, through realistic picture-perfect recreations of the world in graphics, and all the way to providing interactive tools for artistic expression. Key machine learning algorithms will be presented, ranging from classical learning methods (e.g., nearest neighbor, PCA) to deep learning models (e.g., ConvNets, NeRF, deep generative models, including GANs, VAEs, autoregressive models, and diffusion models). Finally, we will discuss image and video forensics methods for detecting synthetic content. In this class, students will learn to build practical applications and create new visual effects using their own photos and videos.

16-730 Robotics Business

Spring: 12 units
This course introduces and develops business concepts that will be useful to new and existing companies, while focusing on robotic technology exemplars. The concepts begin with how to identify a new idea to for a business that can be effectively started. Initial ideas often start as a grandiose plan to change the world and these plans are legitimately the fuel that drive new businesses forward. However, when a company starts (e.g., builds a prototype or writes a first line of code), what is the least product a company can produce that customers still want and need? This kernel and #8212; extracted from the "big plan" and #8212; is a Minimal Viable Product (MVP). Once an MVP business kernel is formulated, we will learn and study how to understand customer needs, how to market a new idea and how raise and manage money for a new business entity. These steps abridge information that can be found in an MBA curriculum, but engineers and scientists focused on the technical side will need this information to participate in the process of building companies. In parallel, we will investigate the marketplace through the stock market. The stock market is a powerful window into the world of business. In other words, when a new business is built it has to live inside the competitive environment of every other business. To understand this eco-system, we will follow several companies in-situ as they go through their own ups-and-downs within the business world. The course is project based. Each student will either build their own business concept, or they will build an improvement plan that would be targeted to improve an existing business. Professor Bourne is a founding member of the Robotics Institute(1979) and has taught business concepts within the Tepper Business School and the Robotics Institute since 1988. In addition, he is the President of his own company Design One Software.

16-735 Ethics and Robotics

Intermittent: 12 units
This course contextualizes robotics, AI, and machine learning within cultural conversation, ethics, and power relationships in society. It will draw upon "AI and Humanity" as well as numerous other texts, including Mindless by Simon Head, Drone Theory by Gr and #233;goire Chamayou, and news articles. The course will culminate in team-based design and futuring project addressing the ways in which robotic technologies will influence society and values in the near future. Our target audience is students who will participate in computer science and robotics research and can use this course to inform future research and career decisions.

Course Website: https://vdean.github.io/16-735-ethics-robotics.html

16-737 Special Topic: Research to Startup: creating a startup from robotics research

Intermittent: 12 units
(This course is offered only to Ph.D. students in SCS, or with instructor permission.) This course is for Ph.D. students interested in exploring turning their research into a startup. Advances in AI and robotics have opened exciting opportunities for robotics-based startups. But with that comes challenges. In this class, students will form small teams to take an idea based in part on their research and work through the early steps of converting it into a company. This will require taking a dispassionate view of your research as a product or service and assessing its market and value. Each team will work through customer discovery, vetting ideas, creating and communicating a vision and strategy, fundraising, and building a product. We will have guest lectures and discussions where we will learn from the experiences of people who have created startups. We will learn about CMU resources to help with IP and technology transfer and discuss open-source strategies. We will discuss leveraging Ph.D. students' honed research skills to be successful company founders and #8212;e.g., related work investigations, presentations, and time management. We will emphasize the difference between research and commercial software and provide tools, technologies, and methodologies for a software development lifecycle. We cannot cover everything you need to know in one semester, but we will expose you to the essential aspects necessary to get started.

16-740 AI for Manipulation

Spring: 12 units
Manipulation is the process of changing the state of objects through direct physical interactions. To perform manipulation tasks in unstructured environments, autonomous robots will need to learn about the objects in their surroundings as well as the skills required to manipulate and change the state of these objects. In this course, we explore the use of machine learning and data-driven algorithms for robot manipulation. The course introduces students to the wide variety of challenges posed by manipulation tasks, and how these challenges can be formulated as learning problems. Students are taught how these problems can be solved using machine learning techniques. The types of machine learning methods covered in this course include supervised, unsupervised, active, and reinforcement learning methods. The course includes both lectures and guided paper discussions.

16-741 Mechanics of Manipulation

Fall: 12 units
Mechanics of Manipulation is a graduate level course that dives into the fundamentals of robotic manipulation. Through this course you will learn the kinematics, statics, and dynamics of robotic manipulators as they interact with the world to accomplish tasks. You will gain experience with the intelligent use of kinematic constraint, gravity, and frictional forces. Additional topics include rigid body mechanics, automatic planning based on mechanics, deformable manipulation, and simulation of dynamic manipulation. Applications of robotic manipulation are drawn from physical human-robot interaction, manufacturing, and other domains.

Course Website: http://www.cs.cmu.edu/afs/cs/academic/class/16741-s07/www/index.html (http://www.cs.cmu.edu/afs/cs/academic/class/16741-s07/www/)

16-742 Geometry of Locomotion

Fall: 12 units
This course introduces geometric methods for the analysis of locomoting systems. Focusing on the kinematics of locomoting systems, the course covers topics from differential geometry, geometric mechanics, and motion planning . Specific topics include configuration spaces, manifolds, groups, Lie groups, representations of velocity, holonomic and nonholonomic constraints, constraint curvature, response to cyclic inputs and distance metrics. The primary goal of this class is to develop an intuitive understanding of these concepts and how they are used in locomoting systems, rather than working through a set of formal proofs and derivations. We do, however, incorporate enough mathematical formalism for this class to serve as a starting point for further investigation into this topic area. We also call upon biological data, when available, and relate to the mathematical formalisms in the class.

16-745 Optimal Control and Reinforcement Learning

Spring: 12 units
This is a course about how to make robots move through and interact with their environment with speed, efficiency, and robustness. We will survey a broad range of topics from nonlinear dynamics, linear systems theory, classical optimal control, numerical optimization, state estimation, system identification, and reinforcement learning. The goal is to provide students with hands-on experience applying each of these ideas to a variety of robotic systems so that they can use them in their own research.

Course Website: http://www.cs.cmu.edu/~cga/dynopt/

16-748 Underactuated Robots

Fall: 12 units
People and animals move through and interact with the world in a fundamentally dynamic way. In the vast majority of cases the same cannot be said for robots. In fact, many conventional approaches to motion planning and robot control attempt to explicitly cancel out the dynamics associated with different tasks. This class will consider underactuated robots, systems that do not have full control over their state and therefore cannot be planned for or controlled via conventional methods. Our goal will be to make novel locomoting robots act more "naturally." This class will highlight the relationship between conventional ideas from deterministic motion planning and control design (e.g., dynamic programming and linear-quadratic regulators) and their contemporary counterparts, many of which help form the analytical basis for the probabilisitic reasoning that underlies contemporary AI systems (e.g., POMDPs). Note that this course is inspired by and, for the most part, will follow the format of "Underactuated Robotics: Learning, Planning, and Control for Efficient and Agile Machines" created by Prof. Russ Tedrake at MIT. We will take several tangents, but the course materials provided by Prof. Tedrake through MIT Open Courseware are an incredible resource for this course (and really just in general).

16-761 Mobile Robots

Spring: 12 units
The course is targeted to graduate level students. The lectures will develop the fundamentals for enabling autonomy of multi rotor aerial vehicles. Students will individually complete assignments related to autonomous quadrotor flight, including motion planning, control, dynamics, state estimation, and perception. The class will culminate in a final project in which students may work together in groups or individually to enhance the autonomy capabilities developed through the assignments.

Course Website: https://mr-cmu.github.io

16-762 Mobile Manipulation

Spring: 12 units
In this project-based course, you'll learn about mobile manipulation through hands-on experience working with real mobile manipulators. You'll gain experience with teleoperation, autonomy, perception, navigation, manipulation, and human-robot interaction, all within the context of mobile manipulators. You'll also learn about robot design, collaborative research, and applications for mobile manipulators.

16-765 Robotics & AI for Agriculture

Spring: 12 units
Robotics and artificial intelligence technologies have the potential to increase the efficiency, long-term sustainability, and profitability of agricultural production methods. This class will introduce common aspects of agricultural systems, the AI/Robotics tools that are being used to address them, and key research challenges looking forward. Technical topics include IoT sensor networks, in-field computer vision, 3D crop mapping and modeling, mobile robot navigation, and robotic manipulation of plants. Course sessions will be split evenly between lectures by the instructor and student-led discussion of relevant papers from the contemporary research literature.

16-778 Mechatronic Design

Spring: 12 units
Mechatronics is the synergistic integration of mechanism, electronics, and computer control to achieve a functional system. This course is a semester-long multidisciplinary capstone hardware project design experience in which small (typically four-person) teams of electrical and computer engineering, mechanical engineering and robotics students deliver an end-of-course demonstration of a final integrated system capable of performing a mechatronic task. Throughout the semester, the students design, configure, implement, test and evaluate in the laboratory devices and subsystems culminating in the final integrated mechatronic system. Lectures will complement the laboratory experience with comparative surveys, operational principles, and integrated design issues associated with the spectrum of mechanism, microcontroller, electronic, sensor, and control components.

Course Website: http://www.ece.cmu.edu/courses/items/18578.html

16-782 Planning and Decision-making in Robotics

Fall: 12 units
Planning and Decision-making are critical components of autonomy in robotic systems. These components are responsible for making decisions that range from path planning and motion planning to coverage and task planning to taking actions that help robots understand the world around them better. This course studies underlying algorithmic techniques used for planning and decision-making in robotics and examines case studies in ground and aerial robots, humanoids, mobile manipulation platforms and multi-robot systems. The students will learn the algorithms and implement them in a series of programming-based projects.

16-785 Integrated Intelligence in Robotics: Vision Language Planning

Intermittent: 12 units
This is a project-oriented course that covers interdisciplinary topics on cognitive intelligence in robotic systems. Cognitive abilities constitute high-level, humanlike intelligence that exhibits reasoning or problem-solving skills. Such abilities as semantic perception, use of language, and task planning can be built on top of low-level robot autonomy. The topics covered generally bridge across multiple technical areas, for example, vision-language intersection and language-action/plan grounding. The project theme in Spring 2023 is "movie making" that presents various robotics and machine learning challenges ranging from content generation such as scenario generation or scene/video synthesis/editing to robotics automation such as autonomous camera control or autonomous stop-motion control. This course is composed of 50% lectures and 50% seminar classes. The course objectives will also put a special emphasis on learning research skills, e.g., problem formulation, literature review, ideation, evaluation planning, results analysis, and hypothesis verification. The course is discussion intensive, and thus attendance is required.

Course Website: http://www.cs.cmu.edu/~jeanoh/16-785/

16-791 Applied Data Science

Spring: 12 units
This course explores the rapidly developing field of data science in the context of its pragmatic applications. Applied Data Science strives to achieve three main goals. The first is to optimize the efficacy of decision making by human managers. The second is to maximize the utilization of available data, so that no important clue is ever missed. The third is to improve understanding of data and the underlying processes that produce it. This course aims at building skills required to systematically achieve those goals in practice. The students will gain and solidify awareness of the most prevalent contemporary methods of Data Science, and develop intuition needed for assessing practical utility of the studied topics in application scenarios. They will be able to learn how to formulate analytic tasks in support of project objectives, how to define successful analytic projects, and how to evaluate utility of existing and potential applications of the discussed technologies in practice.

16-792 Applied Machine Learning

Intermittent
This course explores the rapidly developing field of machine learning in the context of its pragmatic applications. The domain of Applied Machine Learning strives to achieve three main goals. The first is to build effective models to optimize the efficacy of decision-making. The second is to maximize the utilization of available data so that no important clue is ever missed. The third is to gain or improve an understanding of data and the underlying processes that produce it. Students are required to register for 9 units to receive credit for lectures but may also register for 12 units which will include 3 units of capstone project.

16-820 Advanced Computer Vision

Fall: 12 units
16-820 is a required core course for MSCV students and is intended to move at a slightly faster pace compared to 16-720. This course introduces the fundamental techniques used in computer vision, that is, the analysis of patterns in visual images to reconstruct and understand the objects and scenes that generated them. Topics covered include camera geometry and calibration, multi-view stereo, 3D reconstruction, image detection, segmentation, and tracking, and physics-based vision. The homeworks involve considerable Python programming exercises.

16-823 Physics-based Methods in Vision (Appearance Modeling)

Intermittent: 12 units
Everyday, we observe an extraordinary array of light and color phenomena around us, ranging from the dazzling effects of the atmosphere, the complex appearances of surfaces and materials, and underwater scenarios. For a long time, artists, scientists, and photographers have been fascinated by these effects, and have focused their attention on capturing and understanding these phenomena. In this course, we take a computational approach to modeling and analyzing these phenomena, which we collectively call "visual appearance". The first half of the course focuses on the physical fundamentals of visual appearance, while the second half of the course focuses on algorithms and applications in a variety of fields such as computer vision, graphics and remote sensing and technologies such as underwater and aerial imaging.
Prerequisites: 16-385 or 16-720 or 15-462 or 16-820

Course Website: http://www.cs.cmu.edu/afs/cs/academic/class/16823-f06/

16-824 Visual Learning and Recognition

Spring: 12 units
This graduate-level computer vision course focuses on representation and reasoning for large amounts of data (images, videos, associated tags, text, GPS locations, etc.) toward understanding the visual world surrounding us. We will be reading an eclectic mix of classic and recent papers on topics including Theories of Perception, Mid-level Vision (Grouping, Segmentation, Poses), Object and Scene Recognition, 3D Scene Understanding, Action Recognition, Multimodal Perception, Language and Vision Models, Deep Generative Models, Efficient Neural Networks, and more. We will cover a wide range of supervised, semi-supervised, self-supervised, and unsupervised approaches for each topic above.
Prerequisites: 15-781 Min. grade B or 16-720 Min. grade B or 16-722 Min. grade B or 10-701 Min. grade B or 16-385 Min. grade B

Course Website: https://visual-learning.cs.cmu.edu/

16-825 Learning for 3D Vision

Spring: 12 units
Any autonomous agent we develop must perceive and act in a 3D world. The ability to infer, model, and utilize 3D representations is therefore of central importance in AI, with applications ranging from robotic manipulation and self-driving to virtual reality and image manipulation. While 3D understanding has been a longstanding goal in computer vision, it has witnessed several impressive advances due to the rapid recent progress in (deep) learning techniques e.g. differentiable rendering, single-view 3D prediction. The goal of this course is to explore this confluence of 3D Vision and Learning-based Methods.

16-831 Introduction to Robot Learning

Fall and Spring: 12 units
Robots need to make sequential decisions to operate in the world and generalize to diverse environments. How can they learn to do so? This is what we call the "robot learning" problem and it spans topics in machine learning, visual learning and reinforcement learning. In this course, we will learn the fundamentals of topics in machine/deep/visual/reinforcement-learning and how such approaches are applied to robot decision making. We will study fundamentals of: 1) machine (deep) learning with emphasis on approaches relevant for cognition, 2) reinforcement learning: model-based, model-free, on-policy (policy gradients), off-policy (q-learning), etc.; 2) imitation learning: behavior cloning, dagger, inverse RL and offline RL.; 3) visual learning geared towards cognition and decision making including topics like generative models and their use for robotics, learning from human videos, passsive internet videos, language models; and 4) leveraging simulations, building differentiable simulations and how to transfer policies from simulation to the real world; 5) we will also briefly touch topics in neuroscience and psychology that provide cognitive motivations for several techniques in decision making. Throughout the course, we will look at many examples of how such methods can be applied to real robotics tasks as well as broader applications of decision making beyond robotics (such as online dialogue agents etc.). The course will provide an overview of relevant topics and open questions in the area. There will be a strong emphasis on bridging the gap between many different fields of AI. The goal is for students to get both the high-level understanding of important problems and possible solutions, as well as low level understanding of technical solutions. We hope that this course will inspire you to approach problems in congnition and embodied learning from different perspectives in your research. (As of 3/21/2023)

Course Website: https://docs.google.com/document/d/1Lx2IkUMvtETH52ZMl7eySZX3yLWQnED746ET9g_tte0/edit?usp=sharing (https://docs.google.com/document/d/1Lx2IkUMvtETH52ZMl7eySZX3yLWQnED746ET9g_tte0/edit/?usp=sharing)

16-833 Robot Localization and Mapping

Spring: 12 units
Robot localization and mapping are fundamental capabilities for mobile robots operating in the real world. Even more challenging than these individual problems is their combination: simultaneous localization and mapping (SLAM). Robust and scalable solutions are needed that can handle the uncertainty inherent in sensor measurements, while providing localization and map estimates in real-time. We will explore suitable efficient probabilistic inference algorithms at the intersection of linear algebra and probabilistic graphical models. We will also explore state-of-the-art systems.

Course Website: http://frc.ri.cmu.edu/~kaess/teaching/16833/Spring2018 (http://frc.ri.cmu.edu/~kaess/teaching/16833/Spring2018/)

16-845 Insects and Robots

Fall: 12 units
This course will cover all facets of modeling, design, fabrication, and analysis of robots operating on the insect scale, with a microrobotics perspective. Insects can perform different tasks, such as manipulation or locomotion, with their small scale bodies varying from 200m to 16cm length. Similarly, we can define a micro-robotic system as an autonomous or semi-autonomous device with features on the micron scale or that make use of micron-scale physics for mobility or manipulation of objects. Due to their small size scales, microrobots will encounter difficulties unlike their macro-scale counterparts, in terms of fabrication and autonomy. In this project-based course, our aim will be on learning the physics of scaling, fabrication paradigms, actuation and sensing strategies, with numerous case studies, and to build an insect-inspired robotic system. We will also discuss multiple applications such as surgical robotics, mobile microrobots, multi-agent systems, and micro/nano manipulation.

16-848 Hands: Design and Control for Dexterous Manipulation

Spring: 12 units
Research related to hands has increased dramatically over the past decade. Robot hand innovation may be at an all time high, with new materials and manufacturing techniques promoting an explosion of ideas. Hands have become a priority in virtual reality and telepresence. Even the study of how people use their hands is seeing the growth of new ideas and themes. With all of this attention on hands, are we close to a breakthrough in dexterity, or are we still missing some things needed for truly dexterous manipulation? In this course, we will survey robotic hands and learn about the human hand with the goal of pushing the frontiers on hand design and control for dexterous manipulation. We will consider the necessary kinematics and dynamics for dexterity, what sensors are required to carry out dexterous interactions, the importance of reflexes and compliance, the role of machine learning in grasping and manipulation, and the challenge of uncertainty. We will explore state of the art manufacturing and design techniques, including innovations in soft robotics and embedded sensing. We will examine the human hand: its structure, sensing capabilities, human grasp choice and control strategies for inspiration and benchmarking. Students will be asked to present one or two research papers, participate in discussions and short research or design exercises, and carry out a final project.

Course Website: http://graphics.cs.cmu.edu/nsp/course/16899-s18/

16-855 Special Topics: Tactile Sensing and Haptics

Spring: 12 units
Touch is an important perception modality for both humans and robots. This course aims at providing an overview of the touch perception system for both robots and humans, and provide students with some hands-on experience with the popular touch sensors and devices. On the side of robot sensing, the course will cover the topics on the working principles and designs of robot touch sensors, signal processing algorithms for tactile sensing, and the application of tactile sensing in different robotic tasks; on the side of haptics, the course will introduce the neurological and cognitive study in human haptic system, and the designs and applications of haptic devices that provide a human-machine interface. The human-machine interface is a core part of Virtual Reality (VR) and teleoperation of robots when touch is involved. The course includes lectures, research paper presentation and discussion, and course projects with tactile sensors or haptic devices.

16-873 Spacecraft Design-Build-Fly Laboratory

Fall and Spring: 12 units
Spacecraft design is a truly interdisciplinary subject that draws from every branch of engineering. This course integrates broad skillsets from mechanical engineering, electrical and computer engineering, computer science, and robotics toward the goal of designing, building, testing, and flying a small spacecraft over the course of two semesters. Students will engage directly in all aspects of the spacecraft mission lifecycle from initial requirements definition through mission operations. YES, WE ARE REALLY GOING TO LAUNCH A SATELLITE INTO SPACE AS PART OF THIS COURSE. Students will work in subsystem teams, each focusing on some aspect of the spacecraft, but will be exposed to many different disciplines and challenges. Practical, hands-on, engineering skills will be emphasized, along with building and testing physical hardware and flight software.

16-874 Spacecraft Design-Build-Fly Laboratory 2

Spring: 12 units
(ENROLLMENT IS BY INSTRUCTOR APPROVAL ONLY) This course is a continuation of 16-/18-873, and together these two courses make a sequence culminating in the launch of the satellite designed and built over two consecutive semesters. Spacecraft design is a truly interdisciplinary subject that draws from every branch of engineering. This course integrates broad skillsets from mechanical engineering, electrical and computer engineering, computer science, and robotics toward the goal of designing, building, testing, and flying a small spacecraft over the course of two semesters. In this, the second semester of the two-semester sequence, students will work in subsystem teams to fabricate spacecraft components and finally integrate them into a complete spacecraft by the end of the semester. YES, WE ARE REALLY GOING TO LAUNCH A SATELLITE INTO SPACE AS PART OF THIS COURSE. Practical, hands-on, engineering skills will be emphasized, along with building and testing physical hardware and flight software.

16-878 Advanced Mechatronic Design

Fall: 12 units
This course is designed for students who have a background in mechatronics by having taken a mechatronics design course or through practice. The course will be a combination of laboratories and lectures and will culminate in a class project. The topics covered will be microcontroller hardware subsystems: timer systems, PWM, interrupts; analog circuits, operational amplifiers, comparators, signal conditioning, interfacing to sensors, actuator characteristics and interfacing; C language features for embedded software, register level programming, hardware abstraction layers, event driven programming, state machines, state charts.

16-879 Medical Robotics

Fall: 12 units
This course presents an overview of medical robotics intended for graduate students and advanced undergraduates. Topics include robot kinematics, registration, navigation, tracking, treatment planning, and technical and medical aspects of specific applications. The course will include guest lectures from robotics researchers and surgeons, as well as observation of surgical cases. The course is open to non-majors who have the requisite background.

16-880 Special Topics: Engineering Haptic Interfaces

Spring: 12 units
This course focuses on addressing challenges in the field of haptics from an engineer's perspective. We will begin by studying human haptic perception and an introduction into psychophysics. We will then study the design and control of haptic systems which provide touch feedback to a user. The class format will include lectures, discussion, paper presentations, laboratories and assignments using hardware that will be shipped to the students, and a class project. This class is designed to be a graduate/advanced undergraduate course and requires a background in dynamic systems, mechatronics, and basic programming. Mechanical prototyping, robotics, and feedback control knowledge are useful skills for this class but are not required.

16-881 Seminar Deep Reinforcement Learning for Robotics

Spring: 12 units
Deep RL has a lot of promise to teach robots how to choose actions to optimize sequential decision-making problems, but how can we make deep RL work in the real world? This is a seminar course in which we read papers related to deep learning for robotics and analyze the tradeoffs between different approaches. We will read mostly state-of-the-art papers that were very recently published (e.g. recent CoRL, RSS), but we will also look at some older papers that use different approaches. The goals of the course are to 1) understand what is needed to make deep learning work for robotics 2) analyze the tradeoffs between different approaches. Each class, 2 papers will be presented. These papers will both achieve a similar robotics task but will use different learning-based approaches. The class will discuss these papers and try to understand the strengths and limitations of the approach described in each paper. The list of papers that we will be discussing this year is still to be determined; please see the website for the list of papers that we have used in past semesters: https://sites.google.com/view/16-881-cmu/paper-lists?authuser=0 The seminar is a great followup course to 16-831, 16-884, 10-403, or 10-703.

Course Website: https://sites.google.com/view/16-881-cmu/home?authuser=0 (https://sites.google.com/view/16-881-cmu/home/?authuser=0)

16-882 Systems Engineering and Applied Robotics

Spring: 12 units
This course is intended for graduate students of all disciplines who are interested in learning about Systems Engineering and its application in the development of interdisciplinary technical systems. The first part of the course introduces students to the models, methods, and techniques of Systems Engineering. The second part of the course is a study on the adaptation of Systems Engineering in the development of novel robotic systems in applied fields. Each student in the class will perform a semester long study on a special topic in Systems Engineering and a critical evaluation of the process in the development of innovative robotics for applications in space, mining, agriculture, mining, and others.

16-883 Special Topics: Provably Safe Robotics

Spring: 12 units
Safe autonomy has become increasingly critical in many application domains. It is important to ensure not only the safety of the ego robot, but also the safety of other agents (humans or robots) that directly interact with the autonomy. For example, robots should be safe to human workers in human-robot collaborative assembly; autonomous vehicles should be safe to other road participants. For complex autonomous systems with many degrees of freedom, safe operation depends on the correct functioning of all system components, i.e., accurate perception, optimal decision making, and safe control. This course deals with both the design and the verification of safe robotic systems. From the design perspective, we will talk about how to assure safety through planning, prediction, learning, and control. From the verification perspective, we will talk about verification of deep neural networks, safety or reachability analysis for closed loop systems, and analysis of multi-agent systems.

Course Website: http://www.cs.cmu.edu/~cliu6/provably-safe-robotics.html

16-884 Deep Learning for Robotics

Fall: 12 units
The goal of this course is to study relevant topics towards building intelligent robots that can learn to act and perceive in the real world. The course material should be a self-contained collection of key topics from the intersection of four research areas geared towards this common goal: a) Robot Learning and amp; Deep RL; (b) Computer Vision; (c) Control; (d) Psychology and amp; Neuroscience. This course is geared mainly towards learning and brainstorming. There will be two classes every week. In this first class, instructor will present an in-depth overview of a topic, and then in the second class, students will present instructor-assigned papers related to that topic. There will be no homeworks and just a course project. In the first quarter, we will cover state-of-the-art topics in robot learning (deep RL, inverse RL, etc.) and control (optimal control, dynamic movement primitives, etc.) by studying classical and recent papers in the area. In the second quarter, we will study the role of perception in control and vice-versa to build methods that can learn from high-dimensional raw sensory input. In the third quarter, we will discuss the state of the current understanding of how the brain integrates action and perception. We will also discuss relevant papers from ontogeny (child development literature in Psychology) and phylogeny (evolutionary development literature in Biology) of biological animals that have inspired ideas in learning and robotics. Finally, in the fourth quarter, we will bring these ideas together to brainstorm potential high-level directions that could guide the development of intelligent robots.

16-885 Special Topics: Tactile Sensing and Haptics

Fall: 12 units
Touch is an important perception modality for both humans and robots. This course aims at providing an overview of the touch perception system for both robots and humans. On the side of robot sensing, the course will cover the designs of robot touch sensors, signal processing algorithms for tactile sensing, and the application of tactile sensing in different robotic tasks; on the side of haptics, the course will introduce the neurological and cognitive study in the human haptic system, and the designs and applications of haptic devices that provide a human-machine interface. The course incorporates lectures, research paper presentations, and discussion. The combination of different modules aims to present both the basics and state-of-art research directions in the field.

16-886 Special Topics: Models & Algorithms for Interactive Robotics

Spring: 12 units
Robot interaction with humans is inevitable: autonomous cars navigate through crowded cities, assistive robots help end-users with daily living tasks, and human engineers iteratively tune robot objective functions. In this graduate seminar class, we will build the mathematical foundations for modeling human-robot interaction, investigate algorithms for robot learning from human data, and develop the tools to analyze the safety and reliability of robots deployed around people. The approaches covered will draw upon a variety of tools such as optimal control, dynamic game theory, Bayesian inference, and modern machine learning. Throughout the class, there will also be several guest lectures from experts in the field. Students will practice essential research skills including reviewing papers, debating, writing project proposals, and technical communication.

16-887 Special Topic: Robotic Caregivers and Intelligent Physical Collaboration

Spring: 12 units
Robotics researchers and futurists have long dreamed of robots that can serve as caregivers. In this project-based course, you'll learn about intelligent physical human-robot collaboration and opportunities for robots that contribute to caregiving. You'll gain hands-on experience with teleoperation, autonomy, perception, navigation, manipulation, human-robot interaction, and machine learning. You'll also learn about robot design, collaborative research, and healthcare robotics.

Course Website: https://zackory.com/rc2023/

16-888 Special Topic: Foldable Robots: Origami-inspired design meets mechatronics

Intermittent: 12 units
The way we make robots have changed dramatically since the limitations on the material space was removed. Instead of using "nuts-and-bolts" approach that helped us to make robust, rigid, industrial robots, we can make light-weight, compliant, conformable robots out of paper, fabric, and polymers. In this class, we will explore foldable robots with a multifaceted perspective: Kinematics, design, fabrication, control, and application. We will design and manufacture mechanisms for targeted applications, such as manipulation, bio-inspiration, medical, architecture, using laminates with integrated joints and limited number of actuators.

16-889 Special Topic: Learning for 3D Vision

Spring: 12 units
Any autonomous agent we develop must perceive and act in a 3D world. The ability to infer, model, and utilize 3D representations is therefore of central importance in AI, with applications ranging from robotic manipulation and self-driving to virtual reality and image manipulation. While 3D understanding has been a longstanding goal in computer vision, it has witnessed several impressive advances due to the rapid recent progress in (deep) learning techniques e.g. differentiable rendering, single-view 3D prediction. The goal of this course is to explore this confluence of 3D Vision and Learning-based Methods.

16-890 Special Topic: Robot Cognition for Manipulation

Intermittent: 12 units
This seminar course will cover a mixture of modern and classical methods for robot cognition. We will review papers related to task planning and control using both symbolic and numeric methods. The goal of this course is to give students an overview of the current state of research on robot cognition.

16-891 Multi-Robot Planning and Coordination

Spring: 12 units
The course provides a graduate-level introduction to the field of multi-robot planning and coordination from both AI and robotics perspectives. Topics for the course include multi-robot cooperative task planning, multi-robot path/motion planning, learning for coordination, coordinating robots under uncertainty, etc. The course will particularly focus on state-of-the-art Multi-Agent Path Finding (MAPF) algorithms that can coordinate hundreds of robots with rigorous theoretical guarantees. Current applications for these technologies will be highlighted, such as mobile robot coordination for warehouses, drone swarm control, and multi-arm assembly. The course includes lectures, research paper presentations and discussions, and course projects.

16-892 Seminar: Multimodal Foundational Models

Fall: 12 units
This course will discuss recent foundation models proposed in the literature, with a focus on vision-language models. Topics include large language models, vision-language models, and vision-audio models. As time allows, this course will also discuss application of such models to visual, audio, and video content generation.
Prerequisite: 16-820

16-895 Understanding and Critiquing Generative Computer Vision

Spring: 12 units
In recent years, there have been significant advances in the field of large-scale generative modeling for visual data, such as DALL·E 2 and Stable Diffusion. This seminar course explores these advances beyond just reading and discussion. The goal is to not only inform state of the art but also develop critical and philosophical thinking among students. The course will involve reading papers, presentations, and discussions. The course will also involve reviewing and developing critical thinking.

16-901 RI-JEDI: Intro to Justice, Equity, Diversity, and Inclusion in Robotics

Fall and Spring: 3 units
This course will be offered in the first six weeks of the Fall semester, and will cover topics related to diversity, equity, and inclusion. This will be a companion course to CS-JEDI: 15-996. The course will be discussion-based and feature guest speakers. This course is offered to both graduate and undergraduate students in the RI. Designed specifically with the needs of PhD students in mind, the course is short, flexible, literature-based, framed through the lens of robotics and computer science, and is geared towards building community. We expect the students to spend and lt; 3 hours per week, almost all self-contained within the class time.

Software Societal Systems Courses

17-200 Ethics and Policy Issues in Computing

Fall and Spring: 9 units
Should autonomous robots make life and death decisions on their own? Should we allow them to select a target and launch weapons? To diagnose injuries and perform surgery when human doctors are not around? Who should be permitted to observe you, find out who your friends are, what you do and say with them, what you buy, and where you go? Do social media and personalized search restrict our intellectual horizons? Do we live in polarizing information bubbles, just hearing echoes of what we already know and believe? As computing technology becomes ever more pervasive and sophisticated, we are presented with an escalating barrage of decisions about who, how, when, and for what purposes technology should be used. This course will provide an intellectual framework for discussing these pressing issues of our time, as we shape the technologies that in turn shape us. We will seek insight through reading, discussion, guest lectures, and debates. Students will also undertake an analysis of a relevant issue of their choice, developing their own position, and acquiring the research skills needed to lend depth to their thinking. The course will enhance students' ability to think clearly about contentious technology choices, formulate smart positions, and support their views with winning arguments.

17-210 Introduction to Social Networks

Spring: 12 units
Course Description What makes a recommendation system on social media effective? Why do YouTube mega-influencers with tens of millions of subscribers exist, yet we have not heard of most of them? Why do echo chambers form and polarization deepen in social media platforms despite the utopian promise of the free flow of information and fluid connectivity between people that these platforms had envisioned? How do professionals land their dream jobs? How does mass adoption of technological innovations happen (e.g., Python, Bitcoin)? Underlying these seemingly unrelated questions is the powerful influence of social networks, the collection of social connections that people form on and offline. This course offers an introduction to the study of social networks as a powerful tool for understanding a wide range of questions and for solving real-world problems arising at the intersection of human social behavior and technological systems. The course first introduces network concepts and their mathematical operationalizations that give social network analysis the versatility for rigorous quantitative analysis. Students will subsequently learn how these building blocks have been applied to analyze and solve a wide range of online social phenomena. Finally, the course will introduce statistical models of networks that enable principled investigation of network formation mechanisms. Throughout this course, students will work towards a final team project that applies network concepts and measures to either (a) describe and/or explain an empirically puzzling social phenomenon with network data, (b) develop a network data collection pipeline that aims to solve a real-world problem, or (c) build a system utiziling the insights from the course that solves a real-world problem. The following class activities throughout the course are intended to support and augment the final project.

17-213 Network Analysis: The Hidden Structures behind the Webs We Weave

Fall: 12 units
Have you wondered how Linux and the subsequent development of open-source software ecosystems could thrive despite weak economic incentives? Why do large-scale complex software systems sometimes fail despite well-developed guardrails and practices? What makes a recommendation system on social media so effective and so toxic at the same time? Why do YouTube mega-influencers with tens of millions of subscribers exist, yet each of us only recognize a handful of them at best? Why do echo chambers form and polarization deepen in social media platforms despite the utopian promise of frictionless connectivity that these platforms initially envisioned? How can you land your dream jobs? How does mass adoption of technological innovations happen (e.g., Python, Bitcoin)? Underlying these seemingly unrelated questions is the powerful influence of social networks, the collection of on- and offline social connections, communications, and collaborations that people form with one another. This course offers an introduction to the study of social networks as a powerful tool for formalizing these wide range of questions, for understanding social dynamics in various settings, and for solving real-world problems arising at the intersection of human social behavior and technological systems. The course first introduces network science concepts and their mathematical operationalizations that give rigorous definitions to fuzzy words we use to describe the social world, such as "status" and "social group". Students will subsequently learn how these network concepts were used to analyze and solve a wide range of puzzling online social phenomena. Finally, the course will introduce statistical models of networks that enable principled investigation of network formation mechanisms.

17-214 Principles of Software Construction: Objects, Design, and Concurrency

Fall and Spring: 12 units
Software engineers today are less likely to design data structures and algorithms from scratch and more likely to build systems from library and framework components. In this course, students engage with concepts related to the construction of software systems at scale, building on their understanding of the basic building blocks of data structures, algorithms, and program and computer structures. The course covers technical topics in four areas: (1) concepts of design for complex systems, (2) object-oriented programming, (3) static and dynamic analysis for programs, and (4) concurrency. At the conclusion of this course, students will have substantial experience building medium-sized software systems in Java or JavaScript.
Prerequisites: (15-122 Min. grade C or 15-121 Min. grade C) and (15-151 Min. grade C or 21-127 Min. grade C or 21-128 Min. grade C)

Course Website: https://www.cs.cmu.edu/~ckaestne/17214/f2021/

17-224 Influence, Persuasion, and Manipulation Online

Fall: 9 units
This course will introduce the fundamental behavioral science of influence, persuasion, and manipulation, and the application of these scientific principles to online campaigns to influence attitudes and behavior. In particular, we will discuss the psychology of persuasion, nudging, social influence, bias, persuasive design, and the ethics of persuasion. Against this background, we will analyze case studies drawn from recent, high profile events such as election campaigns, targeted advertising, sowing political division, memes and virality, impact of social media, and propagation of "fake news." Countermeasures to these tactics will be explored, including personal measures, technologies, and policy.

17-301 Special Topics in Societal Computing: Understanding Cyber Teams

Fall: 9 units
Were you the victim of a ransomware attack today? No? Then you should probably thank your cyber security team! Nowadays, nearly everything modern organizations do is protected by some semblance of a cyber team. These cyber teams come in many forms: security operations center, malware analysis, threat emulation, information technology departments, etc. So what do we know about how these cyber teams operate? In this course cyber teams will be studied through the lens of computational organization theory. Different types of cyber teams will be presented with how they operate within the organization. An array of computational organization theory principles will be explored such as network science, information diffusion, policy analysis, and performance theory. A final project will be completed by each student. This project can be of many types such as policy analysis, virtual experimentation, dynamic network analysis, validation, etc. Students will be using the NetLogo scripting language to complete a project. The project will be created, developed, and presented by the student and approved by the instructor.

17-302 Independent Study Mini Undergraduate

Intermittent
Independent Study Mini

17-303 Cryptocurrencies, Blockchains and Applications

Fall and Spring: 9 units
Cryptocurrencies such as Bitcoin have gained large popularity in recent years, in no small part due to the fantastic potential applications they could facilitate. This course will first provide an overview of the technological mechanisms behind cryptocurrencies and distributed consensus and distributed ledgers ("blockchains"), introducing along the way the necessary cryptographic tools. It will then focus on more advanced blockchain applications, such as "smart contracts," that is, contracts written as code. Finally, the course will also introduce some of the legal and policy questions surrounding cryptocurrencies.

17-313 Foundations of Software Engineering

Fall and Spring: 12 units
Students gain exposure to the fundamental principles of software engineering. This includes both core CS technical knowledge and the means by which this knowledge can be applied in the practical engineering of complex software in real-world settings. Topics related to software artifacts include coding, software architecture, measurement, and quality assurance of various qualities (e.g., robustness, security, performance, maintainability) with static and dynamic analysis, testing, code review, and inspection. Topics related to software process include requirements engineering, process models and evaluation, personal and team development, and supply chain issues including outsourcing and open source. This course has a strong technical focus, a strong focus on developing team skills, and will include both written and programming assignments. Students will get experience with the latest software engineering tools and practices.
Prerequisites: 15-121 or 15-122

Course Website: https://www.cs.cmu.edu/~ckaestne/17313/

17-314 Formal Methods

Fall: 6 units
Scientific foundations for software engineering depend on the use of precise, abstract models for describing and reasoning about properties of software systems. This course considers a variety of standard models for representing sequential and concurrent systems, such as state machines, algebras, and traces. It shows how different logics can be used to specify properties of systems, such as functional correctness, deadlock freedom, and internal consistency. Concepts such as compositionality, abstraction, invariants, non-determinism, and inductive definitions are recurrent themes throughout the course. After completing this course, students will: 1. Understand the strengths and weaknesses of certain models and logics including state machines, algebraic and process models, and temporal logic; 2. Be able to select and describe appropriate abstract formal models for certain classes of systems, describe abstraction relations between different levels of description, and reason about the correctness of refinements; 3. Be able to prove elementary properties about systems described by the models introduced in the course; and 4. Understand some of the strengths and weakness of formal automated reasoning tools. Prerequisites: Undergraduate discrete math including first-order logic, sets, functions, relations, and simple proof techniques such as induction.

17-320 Machine Learning and Sensing for Healthcare

Fall: 12 units
Today's health infrastructure makes it challenging for individuals to equitably access even basic medical resources. In this course, we will learn how to create modern health sensing systems that reimagine the way that healthcare delivery is performed. Specifically, we will learn how to transform ubiquitous smart devices around us like smartphones, speakers, and watches, as well as emerging wearables like earables and smartglasses, into personal medical tricorders that have the ability to provide access to health testing at our fingertips. We will learn how to tap into the rich sensor data streams (e.g. acoustic, vision, IMU) from these devices and understand core techniques in applied signal processing and machine learning to intelligently transform sensor data into clinically-relevant biomarkers which can be used to screen and diagnose diseases at scale. Beyond these techniques, this course delves into the full lifecycle of system building including ideation of frugal designs, iterative prototyping, pilot data collection, visualization, and debugging. Finally, to ensure our systems will have impact in the real-world we will cover important issues of privacy-preserving techniques and regulatory pathways which are important considerations when deploying health research. The course will focus on class discussions, hands-on demonstrations, and tutorials. Students will be evaluated on their class participation, multiple mini projects, and a final team project.

Course Website: https://docs.google.com/spreadsheets/d/1OoZfohCyawAkynDMAQD3k9nH6hHvJ8vueVurtuZs0vo/edit?usp=sharing (https://docs.google.com/spreadsheets/d/1OoZfohCyawAkynDMAQD3k9nH6hHvJ8vueVurtuZs0vo/edit/?usp=sharing)

17-322 Agile Methods

Fall: 6 units
Agile methods refers to a number of software development approaches that adopt self-organization, adaptive planning, evolutionary development, frequent delivery and working closely with and incorporating feedback from customers throughout the development process as their principles of operation to achieve responsiveness. This course will introduce students to two well known agile methods: Scrum and Kanban, connecting their practices to established group dynamics and knowledge management theories to explain why they work and under what circumstances

17-323 Quality Assurance

Fall: 6 units
This class is fundamentally about software quality assurance and control. This course will introduce various quality assurance tools and techniques to software engineering students. Students will build their "quality toolbox" not only with useful tools and techniques, but with the knowledge of when those tools should be used, how to evaluate their results, and what assurances they can provide. The key learning objectives of the course include: 1. Understand software quality: how to define it, analyze it, and measure it. 2. Select the proper analytical tool/technique for a given situation and explore how to analyze results. 3. Understand the strengths and weaknesses of different quality assurance techniques, such as software testing, static analysis, code review, and demonstration. 4. Learn to collect, manage, and evaluate quality metrics. 5. Analyze and verify a variety of software properties including, but not limited to, functionality, security, reliability, and performance. 6. Gain experience with real quality assurance tools including static analysis tools, software testing frameworks, and software quality measurement tools

17-324 Advanced Formal Methods

Fall: 6 units
This course builds on the introductory Models class to cover more advanced techniques for modeling and reasoning about complex software systems. Concepts introduced in this course include abstraction and refinement, declarative specifications, advanced temporal logics, and probabilistic modeling. The course will also explore applications of modeling and automated reasoning techniques in various domains, such as security, distributed computing, and cyber-physical systems. After completing this course, students will: 1. Understand how to specify and reason about operations over complex system structures, 2. Understand relationships between software artifacts at different levels of abstraction; 3. Be able to model and reason about systems with uncertainty and stochastic behaviors; and 4. Understand potential applications of modeling techniques to practical software engineering problems. Prerequisites: Completion of Mini 1: Models of Software Systems. Sections D, PP and G are NOT available for on-campus students. Admission to the class is by approval from the instructor: If you are not a software engineering master's student, send email to garlan@cs.cmu.edu for permission to enroll. The email should briefly describe your background, whether you have taken a course with similar materials as in Mini 1, and why you would like to take the course. The course must be taken for a letter grade (not pass/fail). This is a graduate level course.
Prerequisite: 17-314 Min. grade B

17-331 Information Security, Privacy, and Policy

Fall: 12 units
As layers upon layers of technology mediate increasingly rich business processes and social interactions, issues of information security and privacy are growing more complex too. This course takes a multi-disciplinary perspective of information security and privacy, looking at technologies as well as business, legal, policy and usability issues. The objective is to prepare students to identify and address critical security and privacy issues involved in the design, development and deployment of information systems. Examples used to introduce concepts covered in the class range from enterprise systems to mobile and pervasive computing as well as social networking. Format: Lectures, short student presentations on topics selected together with the instructor, and guest presentations. Target Audience: Primarily intended for motivated undergraduate and masters students with CS background. Also open to PhD students interested in a more practical, multi-disciplinary understanding of information security and privacy.

17-332 Software Project Management

Spring: 6 units
Projects are temporary organizations set up to achieve a one time objective in an agreed time frame. They are characterized by requiring the execution of interrelated, normally non repeating activities, by multidisciplinary groups. Because of its temporary nature and the interrelatedness of its activities, projects require prescriptive planning, budgeting, staffing and risk management. This course will introduce student to fundamental project management techniques and tools such as activity planning, milestone planning, estimation, work breakdown structures, critical paths. The course will also look at hybrid methods such as Milestone Driven Agile Execution and Disciplined Agile Delivery.

17-333 Privacy Policy, Law, and Technology

Fall: 9 units
This course focuses on policy issues related to privacy from the perspectives of governments, organizations, and individuals. We will begin with a historical and philosophical study of privacy and then explore recent public policy issues. We will examine the privacy protections provided by laws and regulations, as well as the way technology can be used to protect privacy. We will emphasize technology-related privacy concerns and mitigation, for example: social networks, smartphones, behavioral advertising (and tools to prevent targeted advertising and tracking), anonymous communication systems, big data, and drones. This is part of a series of courses offered as part of the MSIT-Privacy Engineering masters program. These courses may be taken in any order or simultaneously. Foundations of Privacy (Fall semester) offers more in-depth coverage of technologies and algorithms used to reason about and protect privacy. Engineering Privacy in Software (Spring semester) focuses on the methods and tools needed to design systems for privacy. This course is intended primarily for graduate students and advanced undergraduate students with some technical background. Programming skills are not required. 8-733, 19-608, and 95-818 are 12-unit courses for PhD students. Students enrolled under these course numbers will have extra assignments and will be expected to do a project suitable for publication. 8-533 is a 9-unit course for undergraduate students. Masters students may register for any of the course numbers permitted by their program. This course will include a lot of reading, writing, and class discussion. Students will be able to tailor their assignments to their skills and interests. However, all students will be expected to do some writing and some technical work.

17-334 Usable Privacy and Security

Spring: 9 units
There is growing recognition that technology alone will not provide all of the solutions to security and privacy problems. Human factors play an important role in these areas, and it is important for security and privacy experts to have an understanding of how people will interact with the systems they develop. This course is designed to introduce students to a variety of usability and user interface problems related to privacy and security and to give them experience in designing studies aimed at helping to evaluate usability issues in security and privacy systems. The course is suitable both for students interested in privacy and security who would like to learn more about usability, as well as for students interested in usability who would like to learn more about security and privacy. Much of the course will be taught in a graduate seminar style in which all students will be expected to do a weekly reading assignment and each week different students will prepare a presentation for the class. Students will also work on a group project throughout the semester. The course is open to all graduate students who have technical backgrounds. The 12-unit course numbers (08-734 and 5-836) are for PhD students and masters students. Students enrolled in these course numbers will be expected to play a leadership role in a group project that produces a paper suitable for publication. The 9-unit 500-level course numbers (08-534 and 05-436) are for juniors, seniors, and masters students. Students enrolled in these course numbers will have less demanding project and presentation requirements.

17-335 Software Architectures

Spring: 6 units
Successful design of complex software systems requires the ability to describe, evaluate, and create systems at an architectural level of abstraction. This course introduces architectural design of complex software systems. The course considers commonly-used software system structures, techniques for designing and implementing these structures, models and formal notations for characterizing and reasoning about architectures, tools for generating specific instances of an architecture, and case studies of actual system architectures. It teaches the skills and background students need to evaluate the architectures of existing systems and to design new systems in principled ways using well-founded architectural paradigms. After completing this course, students will be able to: 1. describe an architecture accurately 2. recognize major architectural styles in existing software systems 3. generate architectural alternatives for a problem and choose among them 4. construct a medium-sized software system that satisfies an architectural specification 5. use existing definitions and development tools to expedite such tasks 6. understand the formal definition of a number of architectures and be able to reason about the properties of those architectures 7. use domain knowledge to specialize an architecture for a particular family of applications.

17-336 Applied Distributed Systems

Spring: 6 units
Modern computing systems are frequently hosted on the cloud. That is, they are inherently distributed systems. To appropriately build and deploy these systems developers should know not only about development tools such as container management tools but also the structure of the cloud - in particular how it utilizes virtual machines, containers and networks. They should also understand security mechanisms both in the internet and how to authorize users and maintain credentials securely. Finally, to protect the system once it is placed into production, a developer needs to know how to enable the detection of problems during execution through collection and navigation of logs produced by the system. These are the topics covered by this course.

17-338 Network Analysis: The Hidden Structures behind the Webs We Weave

Fall: 12 units
Previously Course number 17213 Have you wondered how Linux and the subsequent development of open-source software ecosystems could thrive despite weak economic incentives? Why do large-scale complex software systems sometimes fail despite well-developed guardrails and practices? What makes a recommendation system on social media so effective and so toxic at the same time? Why do YouTube mega-influencers with tens of millions of subscribers exist, yet each of us only recognize a handful of them at best? Why do echo chambers form and polarization deepen in social media platforms despite the utopian promise of frictionless connectivity that these platforms initially envisioned? How can you land your dream jobs? How does mass adoption of technological innovations happen (e.g., Python, Bitcoin)? Underlying these seemingly unrelated questions is the powerful influence of social networks, the collection of on- and offline social connections, communications, and collaborations that people form with one another. This course offers an introduction to the study of social networks as a powerful tool for formalizing these wide range of questions, for understanding social dynamics in various settings, and for solving real-world problems arising at the intersection of human social behavior and technological systems. The course first introduces network science concepts and their mathematical operationalization's that give rigorous definitions to fuzzy words we use to describe the social world, such as "status" and "social group". Students will subsequently learn how these network concepts were used to analyze and solve a wide range of puzzling online social phenomena. Finally, the course will introduce statistical models of networks that enable principled investigation of network formation mechanisms.

Course Website: https://bvasiles.github.io/networks/

17-340 Green Computing

Intermittent: 9 units
Note: Previously offered as 08-340. Energy is a key societal resource. However, our energy usage is rising at an alarming rate and therefore it has become critical to manage its consumption more efficiently for long term sustainability. This course introduces students to the exciting area of "Green Computing", and is organizationally divided into two tracks. The first track is "Energy-Efficient Computing", which considers the state of the art techniques for improving the energy efficiency of mobile devices, to laptop and desktop class computers and finally to data centers. We will cover energy efficiency across the hardware/software stack, starting from the individual components like processors and radio interfaces to system level architectures and optimizations. The second track is "Applying Computing towards Sustainability", covering topics that leverage computing to reduce the energy footprint of our society. In particular, we will focus on Smart Buildings and the Smart Grid, covering topics such as sensing, modeling and controlling the energy usage of buildings, new operating systems or software stacks for the smart infrastructure, as well as the privacy and security issues with the new "internet of things". The goal of this course is to help students acquire some of the knowledge and the skills needed to do research in this space of "Green Computing". Although the course is listed within SCS, it should be of interest to students in several departments, including ECE, MechE, CEE, EPP and Architecture.

17-346 DevOps and Continuous Integration

Spring: 6 units
DevOps: Engineering for Deployment and Operations": DevOps is the term given to a modern movement to establish practices that significantly reduce the time to production of committed code. This time involves deployment - the period between the completion of the code by the developers and the placing of the code into normal production and dealing with operations issues. Deployment time can be days, weeks, or even months when using normal development practices. Operational issues such as dealing with incidents and errors introduce other delays. Modern internet companies deploy a system multiple or even dozens of times every day. Achieving this velocity requires coordinated process and design activities together with supporting tooling. This course will cover the deployment process and the associated tooling, it will highlight reasons why release schedules can be slow, and it will introduce the practices that are used to enable high velocity deployments. It will also cover the kinds of problems that are created because of high velocity and how modern internet companies deal with these problems. Please note: This is a required course for MSE-SS students. Students outside of the software engineering department may take this course but students of the MSE programs will have first priority.
Prerequisite: 17-336 Min. grade B

17-350 Information Technology Policy: Evidence, Communication, & Advocacy

Spring: 9 units
In recent decades, developments in Information and Communication Technologies (ICTs) have rapidly moved from research environments to products and services used by billions of people. This rapid rate of change has often resulted in a public which does not understand the technologies shaping their lives and lawmakers who are poorly equipped to make sound policy. It is therefore incumbent upon specialists to communicate how ICTs work to the public and lawmakers so policy making is shaped by evidence and reflects public desires. This course will train students to be effective communicators and advocates in the ICT space. Students taking this course will learn about the broader scope of technology policymaking including formal lawmaking, agency rule-making, strategic litigation, and corporate social responsibility. Current ICT policy topics in privacy, free expression, net neutrality, and competition will be covered. Public communication strategies such as writing op-eds, interviewing with journalists, producing explanatory videos and interactive games will be explored. Finally, students will learn how to perform an expert role in areas such as writing policy briefs and providing testimony. The course is open to advanced undergraduate and graduate students. Graduate students whose research has public policy implications are encouraged to develop projects related to their research. There is no requirement for programming knowledge, but students with experience in developing interactive media and games will be encouraged to utilize such skills. The class will focus heavily on readings, critical evaluation of real ICT advocacy campaigns, and homework will provide hands-on experience with numerous strategies for public engagement. At the end of the semester students will have a portfolio of projects which they may release publicly.

17-355 Program Analysis

Fall and Spring: 12 units
This course covers both foundations and practical aspects of the automated analysis of programs, which is becoming increasingly critical to find software errors and assure program correctness. The theory of abstract interpretation captures the essence of a broad range of program analyses and supports reasoning about their correctness. Building on this foundation, the course will describe program representations, data flow analysis, alias analysis, interprocedural analysis, dynamic analysis, Hoare Logic and verification, program synthesis and repair, model checking, and symbolic execution. Through assignments and projects, students will design and implement practical analysis tools that find bugs and verify properties of software. This course satisfies the Logic and Languages constrained elective category of the Computer Science major, the Theoretical Foundations requirement of the Computer Science master's degree, and the Technical Software Engineering requirement for the Software Engineering minor.
Prerequisites: 15-251 Min. grade C and (17-214 or 15-150 Min. grade C)

Course Website: https://cmu-program-analysis.github.io/

17-356 Software Engineering for Startups

Spring: 12 units
Startup engineering is critical to innovation. The skills required to effectively prototype, launch, and scale products are vital to engineers everywhere, from fledgling companies founded in dorm rooms to local mid-size companies to internal startups from multi-national tech giants. However, developing software in a startup environment poses unique engineering challenges. These challenges include making and justifying foundational architectural and technical decisions despite extreme uncertainty; rapidly prototyping and evaluating new ideas and features, while building minimum viable products; prioritizing engineering effort in severely constrained environments; and communicating effectively both within a small engineering team and with internal and external non-technical stakeholders. This course teaches the skills necessary to engineer successfully in a startup environment, through lectures, group projects, case study discussions, and guest speakers drawn from experienced, practicing startup engineers. This is an engineering-focused course; no entrepreneurship background is required or expected. Students do not need to have a startup idea to participate fully.
Prerequisites: 15-213 or 17-514 or 17-214 or 15-214

17-363 Programming Language Pragmatics

Fall: 12 units
This course provides a broad and pragmatic foundation in the most basic tool of the programmer: programming languages. It starts with the fundamentals of syntax, parsing, and binding, the core structural concepts in programming languages. The course will then cover program semantics and type systems, and students will learn to relate them with a type soundness theorem. Finally, a coverage of intermediate optimization and code generation offers the opportunity to discuss both producing efficient code and reasoning about the correctness of program transformations. Assignments involve a combination of tool-assisted formal reasoning and proofs about programming languages, and implementing these language constructs in a compiler. This course fulfills the Logic and amp; Languages constrained elective of the B.S. in Computer Science. Students with substantial math and programming experience who have not satisfied the specific prerequisites can contact the instructor for permission to enroll.
Prerequisites: 15-150 Min. grade C and (21-228 Min. grade C or 15-251 Min. grade C)

Course Website: http://www.cs.cmu.edu/~aldrich/courses/17-363/

17-396 Language Design and Prototyping

Spring: 12 units
Many programmers think of programming languages as having a fixed, standard set of features and #8212;but in fact, languages are being extended all the time, and new languages are constantly being developed, providing great expressive power. In this course, students will learn about techniques for designing and prototyping programming languages. Design topics include language features, a practical approach to semantics, conceptual design techniques, and examples of both general purpose and domain-specific language designs. Prototyping topics include interpreters, source-to-source translators, languages as libraries, and paper prototyping techniques used for lightweight user evaluations. In course assignments, students will practice design and prototyping techniques, implementing prototype languages in several different styles. The course will end with a project in which students design, implement, and evaluate their own programming language.
Prerequisites: 17-214 or 17-514 or 15-213

Course Website: http://www.cs.cmu.edu/~aldrich/courses/17-396/

17-397 Intro to Qualitative Research: Social Media Apps and Video Content Creation

Spring: 12 units
Short-video apps, such as TikTok, have revealed themselves to be highly accessible and increasingly ubiquitous in regards to online social interaction and are currently the most popular social media among mostly young(er) users. This course focuses on how humans as users interact with and understand social technology and how the use of social media apps is connected to and integrated into our everyday life by asking questions like: What are users' motivations to participate in video creation and sharing on social media? What are their practices, strategies, and routines in creating short-form videos as part of digital online culture? What do they know about socio-technical aspects in using short-video apps and creating short-form video content? How does their understanding of socio-technological aspects influence their use of social media apps? This course is designed to enable students to develop and conduct their own individual research project. For this, students will learn how to design, conduct, and analyze qualitative interviews to research socio-technical, cultural, and political perspectives of usage of and engagement with short-form videos and short-video apps, such as TikTok. The course instructor will closely mentor and supervise students' research projects throughout the semester and will provide expertise and background in qualitative methods and social media research to guide students through the research process.

17-400 Machine Learning and Data Science at Scale

Fall and Spring: 12 units
Datasets are growing, new systems for managing, distributing, and streaming data are being developed, and new architectures for AI applications are emerging. This course will focus on techniques for managing and analyzing large datasets, and on new and emerging architectures for applications in machine learning and data science. Topics include machine learning algorithms and how they must be reformulated to run at scale on petabytes of data, as well as data management and cleaning techniques at scale. In addition to large-scale aspects of data science and machine learning, this course will also cover core concepts of parallel and distributed computing and cloud computing, including hands-on experience with frameworks like Spark, streaming architectures like Flink or Spark Streaming, MLlib, TensorFlow, and more. The course will include programming assignments and a substantial final project requiring students to get hands-on experience with large-scale machine learning pipelines or emerging computing architectures.
Prerequisites: 15-214 or 17-214 or 17-514 or 10-601 or 10-301 or 15-211 or 10-701

Course Website: http://euro.ecom.cmu.edu/program/courses/tcr17-803 (http://euro.ecom.cmu.edu/program/courses/tcr17-803/)

17-401 Software Engineering for AI-Enabled Systems

Fall: 12 units
New Course Need Description

Course Website: https://ckaestne.github.io/seai/

17-402 AI and Emerging Economies

Intermittent: 3 units
The course will cover some of the unique aspects of emerging economies as it relates to AI consumption and responsible AI development. The importance of local data and domain knowledge will be illustrated. Germane to budding technologists, entrepreneurs and policy influencers. Multi-disciplinary.

17-405 Grand Challenges in AI: Past, Present and Future

Intermittent: 3 units
Innovative, bold initiatives that capture the imagination of researchers and system builders are often required to spur a field of science or technology forward. A vision for the future of artificial intelligence was laid out by Turing Award winner and Moza Bint Nasser University Professor at CMU, Raj Reddy in his 1988 Presidential address to the Association for the Advancement of Artificial Intelligence. It is time to provide an accounting of the progress that has been made in the field, over the last three decades, toward the challenge goals. While some tasks such as the world-champion chess machine were accomplished in short order, many others, such as self-replicating systems, require more focus and breakthroughs for completion. A new set of challenges for the current decade is also proposed, spanning the health, wealth, and wisdom spheres. The above - plus commentary from half a dozen AI thought leaders - forms the basis of an article in the 2021 Spring Issue of AI Magazine.

17-413 Software Engineering Practicum

Spring: 12 units
This course is a project-based course in which students conduct a semester-long project for a real client in small teams. This is not a lecture-based course; after the first few weeks the course consists primarily of weekly team meetings with the course instructors, with teams making regular presentations on their software development process. Students will leave the course with a firsthand understanding of the software engineering realities that drive SE practices, will have concrete experience with these practices, and will have engaged in active reflection on this experience. After the course, students will have the teamwork, process, and product skills to be immediately competent in a software engineering organization, and will be able to evaluate the new processes and techniques they will encounter in the workplace.
Prerequisite: 17-313

17-415 Software Engineering Reflection

Fall: 6 units
This course is an opportunity to reflect on a software engineering experience you have had in industry. It is structured as a writers workshop, in which you will work with the instructor and other students to identify and flesh out a software engineering theme that is illustrated by your industry experience. You will prepare a 10-page report on this theme, comparable to a practitioner's report at a conference like ICSE or OOPSLA, and a 30-minute presentation to match. This course fulfills a requirement of the Software Engineering Minor program, but students in other programs may take the course if they meet the prerequisite industry experience and if space is available.

17-416 AI Governance: Identifying & Mitigating Risks in Design & Dev of AI Solutions

Fall and Spring: 6 units
With AI and ML finding their way into an increasingly broad range of products and services, it is important to identify and mitigate the risks associated with the adoption of these technologies. This course reviews the different types of risks associated with AI and discusses methodologies and techniques available to identify and mitigate these risks. The course introduces students to ethical frameworks available to identify and analyze risks. It also examines best practices emerging from both government and industry efforts in this area. This includes looking at new regulations such as the EU AI Act as well as emerging frameworks such as the one developed by NIST. The course also examines frameworks developed by leading companies and how these frameworks combine both technical and non-technical approaches. It further discusses changes that need to be enacted by organizations to adopt more systematic approaches to AI governance. This course combines a mix of technical, policy, and management discussions.

17-422 Building User-Focused Sensing Systems

Fall and Spring: 12 units
These days we are surrounded by sensing and computation. Smart devices, such as smartphones, smartwatches, are packed with sensors. While they are already very useful devices, we have only started to scratch the surface here. The aim of this class will be to introduce the students to building and understanding smart sensing devices. The course will include discussion into contribution of various fields, including human-computer interaction, embedded computing, computer vision, distributed systems, machine learning, signal processing, security, and privacy. We will discuss how these various disciplines are coming together to form an end-to-end system that generates useful and user-actionable data. We will take a hands-on approach towards building and evaluating these systems. The students will gain practical experience in developing sensing systems in different application domains, such as activity recognition, health sensing, gestural interaction, etc. You will learn about embedded systems and understand the advantages and limitations of different platforms. You will learn about sensors and how to interface them with the real world to be able to get useful and actionable data. You will learn how to build a network of sensors that can communicate with each other. You will also learn about storing the sensor data for visualization, analysis and presentation both locally and to the cloud. The course will be a combination of lectures, tutorials, class discussions, and demonstrations. Students will be evaluated based on 5 mini-projects/assignments, class participation, weekly reading summaries, and a final project. All hardware resources will be provided to the students and they will be given an option to take their final prototypes with them for the cost of the hardware components. Students should have reasonable programming experience and an interest in tinkering.

Course Website: https://synergylabs.org/courses/17-722/

17-423 Designing Large-scale Software Systems

Spring: 12 units
Design plays a crucial role in the success of a software product, as decisions made during the design stage have a long-lasting impact on qualities such as reliability, robustness, maintainability, scalability, and security. With the increasing use of AI-based programming tools (such as ChatGPT and Copilot), being able to effectively design large, complex software and reason about systems at scale will become highly sought-out skills in the software industry. This course teaches students how to design complex, large-scale software systems that are reliable, robust, and built to last. It introduces fundamental concepts and techniques for designing software to achieve qualities of a successful product (such as maintainability, scalability, and robustness) and to avoid catastrophic failures. After taking this course, students will be able to (1) systematically generate and explore design alternatives, (2) specify and evaluate design options using appropriate abstractions, and (3) communicate and critique design decisions with other members of large, multi-team organizations. The discussions of these concepts will be driven by case studies of past failures and successes in real-world software systems. The course will be hands-on and involve a semester-long project where the students will work in teams and collaborate with other teams to design, test, and deploy a complex software system. This course is aimed at both undergraduate and graduate students who are interested in the role of a software architect or designer in an organization.

Course Website: https://cmu-swdesign.github.io/

17-428 Machine Learning and Sensing

Fall: 12 units
Machine learning and sensors are at the core of most modern computing devices and technology. From Amazon Echo to Apple Watch to Google Photos to self-driving cars, making sense of the data coming from powerful but noisy sensors is the key challenge. The aim of the course will be to explore this intersection of sensors and machine learning, understand the inner workings on modern computing technologies, and design the future ones. We will cover data collection, signal processing, data processing, data visualization, feature engineering, machine learning tools, and some prototyping technologies. The course will focus on class discussions, hands-on demonstrations, and tutorials. Students will be evaluated on their class participation, multiple mini projects, and a final team project.

17-437 Web Application Development

Fall and Spring: 12 units
This course will introduce concepts in programming web application servers. We will study the fundamental architectural elements of programming web sites that produce content dynamically. The primary technology introduced will be the Django framework for Python, but we will cover related topics as necessary so that students can build significant applications. Such topics include: HTTP, HTML, CSS, Javascript, JSON, Design Patterns, Relational and Non-relational Databases, Object-Relation Mapping tools, Security, Web Services, Cloud Deployment, Internationalization, and Scalability and Performance Issues. Students must be comfortable programming in Python to register for this course. Students must provide their own computer hardware for this course. Please visit the Course URL for more information about the course.
Prerequisites: 18-613 or 15-213 or 18-213 or 14-513 or 17-214 or 15-214 or 17-514 or 15-513

Course Website: https://www.cmu-webapps.org/static/index/syllabus.pdf

17-442 Software Management Theory

Spring: 6 units
This course will look at software development from an organizational perspective and its designed for students who want to understand the relationship between business context, software development processes, knowledge creation, culture and organizational structure with the purpose of becoming change agents or manage the software development function at the department, business unit level or above. The course will also highlight the need to follow good work principles in order to avoid ethical failures as evidenced by recent affairs

17-443 Quality Management

Spring: 6 units
Managing software quality is a critical part of all software projects. Software engineers must consider quality during every phase of a project from inception to delivery and beyond. This class will introduce students to the managerial challenges of developing high quality software systems. The key learning objectives of this course include: 1. Define a quality management process in the context of a software project. 2. Understand the costs associated with achieving quality goals and not achieving them 3. Understand the tradeoffs required to implement quality assurance techniques. 4. Gain experience using collected quality metrics to inform project-level decisions.
Prerequisite: 17-323 Min. grade B

17-445 Machine Learning in Production

Fall and Spring: 12 units
The course takes a software engineering perspective on building software systems with a significant machine learning or AI component. It discusses how to take an idea and a model developed by a data scientist (e.g., scripts and Jupyter notebook) and deploy it as part of scalable and maintainable system (e.g., mobile apps, web applications, IoT devices). Rather than focusing on modeling and learning itself, this course assumes a working relationship with a data scientist and focuses on issues of design, implementation, operation, and assurance and how those interact with the data scientist's modeling. This course is aimed at software engineers who want to understand the specific challenges of working with AI components and at data scientists who want to understand the challenges of getting a prototype model into production; it facilitates communication and collaboration between both roles.

Course Website: https://ckaestne.github.io/seai/

17-446 DevOps and Continuous Integration

Spring: 6 units
TBD
Prerequisite: 17-336 Min. grade B

17-450 Crafting Software

Fall and Spring: 12 units
Do you use programming to solve problems in your field of study? Do you know enough to be dangerous, but wish you could be proud of your code? This course aims to provide students with sufficient knowledge and skills to use programming as part of their work. In this class, you will learn how to identify and find problems in your code. You will learn to read, parse, organize, and transform data. We will teach you to write code collaboratively and refine your programs so others can use them.The course will be a mixture of lecture and guided exercise with a recitation focused on hands on instruction. In this course, students are expected to have been exposed to some basic programming concepts, such as variables, if-statements, loops, and arrays. However, students are not expected to have extensive programming experience. This course is not appropriate for students that have completed more than two courses involving programming. We expect students in this class to have diverse backgrounds and experience. Some students will be self-taught, while others will have taken a programming course such as 02-201, 15-110, 95-898, or the library's Software Carpentry workshop. If you have questions about your background and the fit for this class, please don't hesitate to reach out to the instructors.

17-470 Virtual Machines and Managed Runtimes

Fall: 12 units
Traditional compiler and programming language courses focus on language implementations that generate code statically (offline) for a target machine. Yet in today's landscape, many programming languages run on virtual machines where either a virtual instruction set architecture (bytecode) or the source code of the program is translated (and optimized) dynamically for an underlying machine. Such languages come with additional challenges beyond traditional compilation as taught in courses, including efficient representation of high-level language constructs and automatic memory management in the form of garbage collection. Together, the components of the virtual machine and services form what is known as a managed runtime system. This course focuses on implementation techniques for managed runtime systems. Students will learn the basics of virtual machine implementation and build working prototypes to run actual programs. Prior knowledge of compilers and some familiarity with programming language implementation is required.
Prerequisites: 15-611 or 15-411

17-480 API Design and Implementation

Fall and Spring: 12 units
This class focuses on the design of programming interfaces, the APIs, within larger real-world software and ecosystems. We discuss the history and importance of APIs, and the principles behind designing good APIs. This includes study of specific examples of APIs, both good and bad, for inspiration and precaution. Students gain experience with the major steps of API design: gathering requirements, documenting, testing, implementing, refining, evolving, and reimplementing APIs. The principles taught are largely language-independent, though most examples are in Java or C. Students may be able to do assignments in other languages, within reason.
Prerequisites: 17-214 or 15-214 or 15-213

17-514 Principles of Software Construction: Objects, Design, and Concurrency

Fall and Spring: 12 units
Software engineers today are less likely to design data structures and algorithms from scratch and more likely to build systems from library and framework components. In this course, students engage with concepts related to the construction of software systems at scale, building on their understanding of the basic building blocks of data structures, algorithms, and program and computer structures. The course covers technical topics in four areas: (1) concepts of design for complex systems, (2) object-oriented programming, (3) static and dynamic analysis for programs, and (4) concurrency. At the conclusion of this course, students will have substantial experience building medium-sized software systems in Java or JavaScript.
Prerequisites: (15-122 Min. grade C or 15-121 Min. grade C) and (21-128 Min. grade C or 21-127 Min. grade C or 15-151 Min. grade C)

Course Website: https://www.cs.cmu.edu/~ckaestne/17214/f2021/

17-536 Pervasive and Ubiquitous Computing

Intermittent: 12 units
Note: Previously offered as 08530. The aim of the class will be to explore the area of Ubiquitous Computing (ubicomp) and allow students to work on a variety of small technology projects. Students will be exposed to the basics of building ubicomp systems, emerging new research topics, and advanced prototyping techniques. This course will focus more on class discussions and hands on demonstrations, while formal lectures will be conducted only as needed. Students will be evaluated on their class participation, reading summaries, and mini projects.

17-537 Artificial Intelligence Methods for Social Good

Spring: 9 units
Optimization: mathematical programming, robust optimization, influence maximization Game Theory and Mechanism Design: security games, human behavior modeling, auction and market equilibrium, citizen science Machine Learning: classification, clustering, probabilistic graphical models, deep learning Sequential Decision Making: Markov Decision Processes (MDPs), partially observable MDPs, online planning, reinforcement learning In addition to providing a deep understanding of these methods, the course will introduce which societal challenges they can tackle and how, in the areas of (i) healthcare, (ii) social welfare, (iii) security and privacy, (iv) environmental sustainability. The course will also cover special topics such as AI and Ethics and AI and Humans. The course content is designed to not have too much overlap with other AI courses offered at CMU. Although the course is listed within SCS, it should be of interest to students in several other departments, including ECE, EPP and SDS. The students in this 9-unit course are expected to have taken at least three mathematics courses covering linear algebra, calculus, and probability. The students will work in groups on a systematic literature review or a project exploring the possibility of applying existing AI tools to a societal problem, with a survey paper or technical report and presentation delivered at the end of the semester.

17-562 Law of Computer Technology

Fall: 9 units
A survey of how legislatures and courts cope with rapidly advancing computer technologies and how scientific information is presented to, and evaluated by, civil authorities. The course is also an introduction to the legal process generally and the interaction between the legal system and technology organizations. Topics include: patents, copyrights in a networked world, law of the Internet, free speech, data security, technology regulation, international law, and trans-border crime. Open to juniors, seniors and graduate students in any school. Open to sophomores by permission of the instructor. Prerequisites: none.

17-599 Advanced Topics in Machine Learning and Game Theory

Fall: 12 units
This course is designed to be a graduate-level course covering the topics at the intersection of machine learning and game theory. Recent years have witnessed significant advances in machine learning and their successes in detection, prediction, and decision-making problems. However, in many application domains, ranging from auction and ads bidding, to entertainment games such as Go and Poker, to autonomous driving and traffic routing, to the intelligent warehouse, to home assistants and the Internet of Things, there is more than one agent interacting with each other. Game theory provides a framework for analyzing the strategic interaction between multiple agents and can complement machine learning when dealing with challenges in these domains. Therefore, in the course, we will introduce how to integrate machine learning and game theory to tackle challenges in multi-agent systems. The course will multiple topics as listed below

Course Website: https://feifang.info/advanced-topics-in-machine-learning-and-game-theory-fall-2021/

17-612 Business and Marketing Strategy

Fall and Spring: 6 units
This course prepares technically minded students to understand and use essential business concepts in their careers. With this competency, students will be able to make use of, contribute to, and influence the business, product and marketing decisions that affect engineering and technology decisions, quality, and performance. Students will be better equipped to make business arguments for supporting their product, technology and engineering ideas in their future, too. This 6-unit course emphasizes learning-by-doing to achieve the learning objectives. The teaching and learning approach uses a situation that many students will encounter in their early careers: to conceive, plan and propose a new product idea. Each student works on a course-long project to add a new technology product idea for an existing company's product line. They'll make product, technology, pricing, marketing, and sales decisions to achieve success and support of the company's strategy and business decisions. Their work will culminate in building a compelling business case, with financial projections, to persuade the company executives to invest in the product idea.

Course Website: https://mse.s3d.cmu.edu/

17-619 Introduction to Real-Time Software and Systems

Intermittent: 12 units
Introduction to Real-Time Software and Systems presents an overview of time as it relates engineering complex systems. Any system that responds at the pace of relevant events has real-time constraints whether the timescale is short, like the flight controls for an aircraft, or longer, like the flight reservation system for an airline. Fundamental concepts, terminology, and issues of real-time systems are introduced in this course. The focus is on software solutions to real-time problems-solutions that must be both correct and timely. Software development is examined with emphasis on real-time issues during each phase of the software lifecycle. Real-time requirements analysis, architecting real-time systems, designing and modeling system timing, and implementation and testing strategies are studied. Modeling techniques using UML 2.0 are applied. Particular emphasis is placed on real-time scheduling to achieve desired timing, reliability, and robustness. Languages and operating systems for real-time computing, and real-time problems in concurrent and distributed systems are explored. This course provides a comprehensive view of real-time systems with theory, techniques and methods for the practitioner. After successfully completing this course, the student will be able to identify constraints and understand real-time issues in system development, and propose approaches to typical real-time problems. The aim of this course is to motivate and prepare students to pursue more in-depth study of specific problems in real-time computing and systems development. REQUIREMENT: Proficiency with a high-level programming language such as C or Ada and basic concepts of computing systems. Familiarity with software engineering concepts and system development lifecycle.

17-621 Computer Simulation of Complex Socio-Technical Systems

Intermittent: 12 units
How likely is an intervention like social distancing to save lives? Will a law legislating sanctions against social media platforms that spread disinformation stop the spread? We live and work in complex adaptive and evolving socio-technical systems where questions such as these arise constantly. Questions such as these are often only addressable through computational modeling, i.e., through simulation. Simulation models are a critical method for understanding how to adaptation and learning will change the status-quo. Computational modeling can be used to help analyze, reason about, predict the behavior of, and possibly control complex human systems of "networked" agents. Using simulation it is possible to advance theory, test policies before enacting them, and think through non-linear social effects.

Course Website: http://www.casos.cs.cmu.edu/courses/

17-624 Advanced Formal Methods

Fall: 6 units
This course builds on the introductory Models class to cover more advanced techniques for modeling and reasoning about complex software systems. Concepts introduced in this course include abstraction and refinement, declarative specifications, advanced temporal logics, and probabilistic modeling. The course will also explore applications of modeling and automated reasoning techniques in various domains, such as security, distributed computing, and cyber-physical systems. After completing this course, students will: 1. Understand how to specify and reason about operations over complex system structures, 2. Understand relationships between software artifacts at different levels of abstraction; 3. Be able to model and reason about systems with uncertainty and stochastic behaviors; and 4. Understand potential applications of modeling techniques to practical software engineering problems. Prerequisites: Completion of Mini 1: Models of Software Systems. Sections D, PP and G are NOT available for on-campus students. Admission to the class is by approval from the instructor: If you are not a software engineering master's student, send email to garlan@cs.cmu.edu for permission to enroll. The email should briefly describe your background, whether you have taken a course with similar materials as in Mini 1, and why you would like to take the course. The course must be taken for a letter grade (not pass/fail). This is a graduate level course.
Prerequisite: 17-614 Min. grade B

17-626 Requirements for Information Systems

Fall: 6 units
Software engineering requires understanding the problem, before identifying solutions. In this course, students study ways to elicit and analyze problem statements using scenarios, use cases and mockups.

17-627 Requirements for Embedded Systems

Fall: 6 units
Software engineering requires understanding the problem, before identifying solutions. In this course, students study ways to elicit and analyze problem statements for real-time systems along multiple dimensions, including concurrency, dependability and safety.
Prerequisite: 17-614 Min. grade B

17-634 Applied Machine Learning

Spring: 6 units
Autonomous and intelligent systems increasingly rely on automated decision making based on statistical models used for classification or prediction. The practical application of machine learning requires understanding the underlying theoretical assumptions behind a wide variety of statistical models, how to analyze the performance of such models, and how to integrate models into data processing pipelines. This course introduces students to supervised and unsupervised machine learning in the context of software engineering, including the analysis of natural language in bug reports and mobile app reviews. Techniques covered include latent Dirichlet allocation, TF/IDF, naive Bayes, linear regression, decision trees, and random forests.

17-640 IoT, Big Data, and ML: A Hands-on Approach

Intermittent: 12 units
This course is designed to teach IoT concepts, big data, and machine learning techniques using a hands-on approach. An IoT system simulating an order fulfillment process is central to the hands-on learning of the concepts and techniques. Students will work in 4-5 person teams to enable the system and implement the requirements. In doing so, they will incorporate sound design principles of software engineering acquired in lectures. Students will capture the data generated during the execution of the system as it fulfills orders that are received from a front-end system developed by the students. Students will be expected to prepare, process, and model the data for statistical analysis applying techniques taught in class. They will then visualize, analyze and interpret the results, and implement improvements to obtain a 360-degree experience of a business application using the automated system. This course will provide insight into the ways in which business enterprises think about leveraging technology and software in the management of their production operations. The course prepares students for professional opportunities requiring such skills allowing them to identify use cases that facilitate innovation and promote competitiveness.

17-644 Applied Deep Learning

Spring: 6 units
Deep neural networks have made in-roads in virtually every industry, propelled by exponential increases in compute power and fundamental progress in modeling. Knowledge of these models is fast becoming a key asset for software engineers, as current systems are quickly starting to include many neural components, and the practice of software engineering itself is starting to benefit from neural program assistance (incl. automated bug finding, translation between programming languages). This course equips the next generation of software engineers with knowledge of neural models, the software engineering challenges involved in using these, and hands-on experience with their applications. It teaches both a rich vocabulary of general, essential concepts (including architectures), and recent work on applications of these models, aimed primarily at applications for and in software engineering itself. The course includes a group project aimed at constructing a neural solution for an existing application that will be used to teach the various stages (and their pitfalls) of building and deploying deep learners.

17-651 Models of Software Systems

Fall: 12 units
Scientific foundations for software engineering depend on the use of precise, abstract models for describing and reasoning about properties of software systems. This course considers a variety of standard models for representing sequential and concurrent systems, such as state machines, algebras, and traces. It shows how different logics can be used to specify properties of systems, such as functional correctness, deadlock freedom, and internal consistency. Concepts such as compositionality, abstraction, invariants, non-determinism, and inductive definitions are recurrent themes throughout the course. After completing this course, students will: 1. Understand the strengths and weaknesses of certain models and logics including state machines, algebraic and process models, and temporal logic; 2. Be able to select and describe appropriate abstract formal models for certain classes of systems, describe abstraction relations between different levels of description, and reason about the correctness of refinements; 3. Be able to prove elementary properties about systems described by the models introduced in the course; and 4. Understand some of the strengths and weakness of formal automated reasoning tools. Prerequisites: Undergraduate discrete math including first-order logic, sets, functions, relations, and simple proof techniques such as induction. Sections D, PP and G are NOT available for on-campus students. Admission to the class is by approval from the instructor: If you are not MSE/MSIT-SE/MITS, send email to garlan@cs.cmu.edu for permission to enroll. The email should briefly describe your background, whether you have taken an undergraduate discrete math course, and why you would like to take the course. The course must be taken for a letter grade (not pass/fail). This is a graduate level course.

17-654 Analysis of Software Artifacts

Spring: 12 units
Analysis is the systematic examination of an artifact to determine its properties. This course will focus on analysis of software artifacts and #8212;primarily code, but also including analysis of designs, architectures, and test suites. We will focus on functional properties, but also cover non-functional properties like performance and security. In order to illustrate core analysis concepts in some depth, the course will center on static program analysis; however, the course will also include a breadth of techniques such as testing, model checking, theorem proving, dynamic analysis, and type systems. The course will balance theoretical discussions with lab exercises in which students will apply the ideas they are learning to real artifacts. After completing this course, students will: * know what kinds of analyses are available and how to use them * understand their scope and power,when they can be applied and what conclusions can be drawn from their results * have a grasp of fundamental notions sufficient to evaluate new kinds of analysis when they are developed * have some experience selecting and writing analyses for a real piece of software, applying them and interpreting the results Ph.D. students taking the 17-754 version of the course will gain a broad overview of the analysis research literature and in-depth knowledge of a particular sub-area through a course project. Requirement: A recent discrete math course and programming experience. Strongly Recommended: Models of SW Development course (17-651) before taking this course. This course is for letter grade only (no pass/fail grades). This is a graduate course. Only undergrad SE minors may take this course with the instructor's permission. Please note: Students outside of the software engineering department may take this course but students of the MSE programs will have first priority.

17-663 Programming Language Pragmatics

Fall: 12 units
This course provides a broad and pragmatic foundation in the most basic tool of the programmer: programming languages. It starts with the fundamentals of syntax, parsing, and binding, the core structural concepts in programming languages. The course will then cover program semantics and type systems, and students will learn to relate them with a type soundness theorem. Finally, a coverage of intermediate optimization and code generation offers the opportunity to discuss both producing efficient code and reasoning about the correctness of program transformations. Assignments involve a combination of tool-assisted formal reasoning and proofs about programming languages, and implementing these language constructs in a compiler. This course fulfills the Logic and amp; Languages constrained elective of the B.S. in Computer Science. Students with substantial math and programming experience who have not satisfied the specific prerequisites can contact the instructor for permission to enroll.
Prerequisites: 15-251 Min. grade C and (21-228 Min. grade C or 15-150 Min. grade C)

Course Website: http://www.cs.cmu.edu/~aldrich/courses/17-363/

17-670 Virtual Machines and Managed Runtimes

Fall: 12 units
Traditional compiler and programming language courses focus on language implementations that generate code statically (offline) for a target machine. Yet in today's landscape, many programming languages run on virtual machines where either a virtual instruction set architecture (bytecode) or the source code of the program is translated (and optimized) dynamically for an underlying machine. Such languages come with additional challenges beyond traditional compilation as taught in courses, including efficient representation of high-level language constructs and automatic memory management in the form of garbage collection. Together, the components of the virtual machine and services form what is known as a managed runtime system. This course focuses on implementation techniques for managed runtime systems. Students will learn the basics of virtual machine implementation and build working prototypes to run actual programs. Prior knowledge of compilers and some familiarity with programming language implementation is required.
Prerequisites: 15-411 or 15-611

17-685 Dynamic Network Analysis

Spring: 12 units
Who knows who? Who knows what? Who is influential? What is the social network, the knowledge network, the activity network? How do ideas, products and amp; diseases propagate through groups and impact these networks? Does social media change the way these networks operate? Questions such as these and amp; millions of others require a network perspective and an understanding of how ties among people, ideas, things, and amp; locations connect, constrain and amp; enable activity. In the past decade there has been an explosion of interest in network science moving from the work on social networks and graph theory to statistical and computer simulation models. Network analysis, like statistics, now plays an role in most empirical fields. Network science is a broad and multi-disciplinary field. In this class, students will gain an appreciation of the history of the field, the difference between social networks and social media, the difference graph-based metrics for network analysis and graphical models, the use of traditional and high dimensional network models, and the advances in this field. Applications and issues discussed will include: social media analytics, semantic networks, task networks, organizational design and teams, machine learning and network analysis, generative models, terrorism and crime, health, and fake news. Methods for network data collection, analysis, visualization, and interpretation are covered. Students produce original research in which network data is analyzed using the methods covered in the class

Course Website: http://www.casos.cs.cmu.edu/courses/

17-691 Machine Learning in Practice

Spring: 6 units
As Machine Learning and Artificial Intelligence methods have become common place in both academic and industry environments the majority of resources have focused on methods and techniques for applications. However, there are many considerations that must be addressed when deploying such techniques into practice (or production). The purpose of this course is to cover topics relevant to building a machine learning systems deployed into operations. Such systems have technical requirements including data management, model development, and deployment. However, business/organizational impacts must also be considered. Machine learning systems can be expensive to produce and operate. Students will learn about trade-offs in design, implementation, and expected value. After completing this course, students will: 1. Have the ability to deploy produces with machine learning and AI components; 2. Understand how to implement data pipelines and data engineering systems; 3. Calculate the approximate value provided by a machine learning system to an organization; 4. Understand how to continually assess the value and quality of a deployed machine learning system. Prerequisites: understanding of basic machine learning concepts (i.e. supervised/unsupervised learning). This is a graduate level course.
Prerequisite: 17-634 Min. grade B

17-692 Product Management Essentials I

Fall and Spring: 6 units
This course prepares students to understand and use the essential concepts and practices of product management and innovation. These concepts are used in the critical, early stages of every new product or service idea. Students will acquire the customer-centric knowledge and skills to describe a well-defined, worthwhile customer problem solve; a focused target market of potential customers; specify an innovative and differentiated product solution concept; and design, price and quantify a value proposition that is compelling to customers to buy and use the product. This 6-unit course emphasizes learning-by-doing to achieve the learning objectives. Students work on a hands-on, course-long project focused on a problem space selected by the student and approved by the instructor for course fit.

Course Website: https://mse.s3d.cmu.edu/applicants/course-offerings.html

17-702 Current Topics in Privacy Seminar

Fall and Spring: 3 units
In this seminar course students will discuss recent papers and current public policy issues related to privacy. Privacy professionals from industry, government, and non-profits will deliver several guest lectures each semester.

17-712 Fantastic Bugs and How to Find Them

Fall: 12 units
This advanced course studies the nature of software bugs and security vulnerabilities arising in complex application domains and surveys specialized program analysis + automated testing techniques for identifying such issues proactively. The course will take a tour of various domains such as mobile systems, databases, web browsers, distributed and networked systems, autonomous vehicles, and smart contracts. For each domain, the class will review case studies of high-impact software bugs that have manifested in production and will then discuss state-of-the-art research techniques that aim to uncover such bugs automatically. Apart from the literature review, students will engage significantly with software system design and engineering via hands-on assignments and a semester-long project involving real-world applications and analysis tools for one or more domains. Students completing this course will be able to (a) identify practical challenges of applying well-known program analysis and testing techniques to complex application domains, (b) formulate and leverage domain-specific assumptions for making analysis techniques tractable in a specialized setting, and (c) build practical tools for improving software quality in large-scale systems. The course assumes that students have some background in reasoning about software quality, system security, and/or working with program representations. The course builds upon mathematical principles introduced in foundational classes on program analysis, verification, or compiler design, as well as system design principles encountered in introductory security or software engineering courses. Please check the course website for classes that qualify as sufficient pre-requisites, or contact the instructor to discuss your background.

Course Website: https://cmu-fantastic-bugs.github.io/

17-731 Foundations of Privacy

Fall: 12 units
Privacy is a significant concern in modern society. Individuals share personal information with many different organizations - healthcare, financial and educational institutions, the census bureau, Web services providers and online social networks - often in electronic form. Privacy violations occur when such personal information is inappropriately collected, shared or used. We will study privacy in a few settings where rigorous definitions and enforcement mechanisms are being developed - statistical disclosure limitation (as may be used by the census bureau in releasing statistics), semantics and logical specification of privacy policies that constrain information flow and use (e.g., by privacy regulations such as the HIPAA Privacy Rule and the Gramm-Leach-Bliley Act), principled audit and accountability mechanisms for enforcing privacy policies, anonymous communication protocols - and other settings in which privacy concerns have prompted much research, such as in social networks, location privacy and Web privacy (in particular, online tracking and amp; targeted advertising).

17-733 Privacy Policy, Law, and Technology

Fall: 12 units
NOTE: Previously offered as 08-733. This course focuses on policy issues related to privacy from the perspectives of governments, organizations, and individuals. We will begin with a historical and philosophical study of privacy and then explore recent public policy issues. We will examine the privacy protections provided by laws and regulations, as well as the way technology can be used to protect privacy. We will emphasize technology-related privacy concerns and mitigation, for example: social networks, smartphones, behavioral advertising (and tools to prevent targeted advertising and tracking), anonymous communication systems, big data, and drones. This is part of a series of courses offered as part of the MSIT-Privacy Engineering masters program. These courses may be taken in any order or simultaneously. Foundations of Privacy (Fall semester) offers more in-depth coverage of technologies and algorithms used to reason about and protect privacy. Engineering Privacy in Software (Spring semester) focuses on the methods and tools needed to design systems for privacy. This course is intended primarily for graduate students and advanced undergraduate students with some technical background. Programming skills are not required. 8-733, 19-608, and 95-818 are 12-unit courses for PhD students. Students enrolled under these course numbers will have extra assignments and will be expected to do a project suitable for publication. 8-533 is a 9-unit course for undergraduate students. Masters students may register for any of the course numbers permitted by their program. This course will include a lot of reading, writing, and class discussion. Students will be able to tailor their assignments to their skills and interests. However, all students will be expected to do some writing and some technical work.

17-735 Engineering Privacy in Software

Spring: 12 units
Privacy harms that involve personal data can often be traced back to software design failures, which can be prevented through sound engineering practices. In this course, students will learn how to identify privacy threats due to surveillance activities that enhance modern information systems, including location tracking, behavioral profiling, recommender systems, and social networking. Students will learn to analyze systems to identify the core operating principles and technical means that introduce privacy threats, and they will learn to evaluate and mitigate privacy risks to individuals by investigating system design alternatives. Strategies to mitigating privacy risk will be based on emerging standards and reliable privacy preference data. Students will have the opportunity to study web-, mobile- and cyber-physical systems across a range of domains, including advertising, healthcare, law enforcement and social networking. In addition, students will know how, and when, to interface with relevant stakeholders, including legal, marketing and other developers in order to align software design with privacy policy and law.

17-756 Computational Social Science Research Design and Data Analytics

Spring: 12 units
This course surveys how digital trace data of human activity online, combined with careful research design and data analytics, have led to surprising discoveries and development of novel theoretical explanations in the field of computational social science (CSS). The course has three aims. (a) It is intended to stimulate new ways of formulating research questions on pressing/emerging societal issues of interest (e.g., political polarization, gender representation in open-source software development, decentralized governance based on blockchain technology) given the possibilities afforded by a wide array of digital trace data (e.g., social media, open-source software collaboration, cryptocurrency transactions, satellite imagery). This course will (b) discuss exemplary works in CSS that made novel discoveries or made theoretical and/or methodological breakthroughs and (c) cover practical considerations that commonly arise in a CSS research project cycle. These issues may include, but are not limited to, data collection (sampling methods and bias), repurposing existing datasets that were collected in a different research context, constructing metrics based on theoretical insights, analytic approaches adequate for a given research question (statistical modeling, network analysis, online experiments, simulation-based theory development), big data processing and analytic tools (distributed data processing frameworks, visualization), ethical considerations, and data sharing. In the end, this course will help participants develop "good taste" for theoretically insightful, methodologically creative, and well thought out research, while learning to identify potential pitfalls that could arise in their own research.

17-801 Dynamic Network Analysis

Spring: 12 units
Who knows who? Who knows what? Who is influential? What is the social network, the knowledge network, the activity network? How do ideas, products and amp; diseases propagate through groups and impact these networks? Does social media change the way these networks operate? Questions such as these and amp; millions of others require a network perspective and an understanding of how ties among people, ideas, things, and amp; locations connect, constrain and amp; enable activity. In the past decade there has been an explosion of interest in network science moving from the work on social networks and graph theory to statistical and computer simulation models. Network analysis, like statistics, now plays an role in most empirical fields. Network science is a broad and multi-disciplinary field. In this class, students will gain an appreciation of the history of the field, the difference between social networks and social media, the difference graph-based metrics for network analysis and graphical models, the use of traditional and high dimensional network models, and the advances in this field. Applications and issues discussed will include: social media analytics, semantic networks, task networks, organizational design and teams, machine learning and network analysis, generative models, terrorism and crime, health, and fake news. Methods for network data collection, analysis, visualization, and interpretation are covered. Students produce original research in which network data is analyzed using the methods covered in the class.

Course Website: http://www.casos.cs.cmu.edu/courses/

17-821 Computer Simulation of Complex Socio-Technical Systems

Spring: 12 units
How likely is an intervention like social distancing to save lives? Will a law legislating sanctions against social media platforms that spread disinformation stop the spread? We live and work in complex adaptive and evolving socio-technical systems where questions such as these arise constantly. Questions such as these are often only addressable through computational modeling, i.e., through simulation. Simulation models are a critical method for understanding how to adaptation and learning will change the status-quo. Computational modeling can be used to help analyze, reason about, predict the behavior of, and possibly control complex human systems of "networked" agents. Using simulation it is possible to advance theory, test policies before enacting them, and think through non-linear social effects.

Course Website: http://www.casos.cs.cmu.edu/courses/

17-880 Algorithms for Private Data Analysis

Spring: 12 units
We study the following question in this course: How do we perform useful analysis on a data set that contains sensitive information about individuals without compromising the privacy of those individuals? To study this question, we will introduce differential privacy, a framework of designing data analysis algorithms with strong, meaningful, and mathematically provable privacy guarantees. We will survey a set of algorithmic tools that allow us to privately perform a wide range of statistical analyses. Of course, privacy does not come for free, and we will also study some of the fundamental limitations imposed by the requirement of differential privacy. Through the discussion of these results, we will also demonstrate some of the most novel and surprising connections between differential privacy and other areas of theoretical computer science, including machine learning theory, cryptography, convex geometry, and game theory.

SCS Concentrations

The School of Computer Science (SCS) offers concentrations for SCS students in various aspects of computing to provide greater depth to their education. Computer Science majors can substitute an SCS concentration for the minor requirement. Artificial Intelligence and Computational Biology majors can complete an SCS concentration if they wish, but it is not required for these degrees.

Note: At the present time, concentrations are not shown on official transcripts.

SCS Concentrations are currently available to SCS students only and assume these students have taken most/all of the CS core: 15-122/15-150/15-210/15-213/15-251. For SCS students entering in Fall 2018 or later, these students may not pursue a minor within SCS; instead they can pursue the related concentration. For example, instead of pursuing the Software Engineering minor, these SCS students could pursue the new Software Engineering concentration.

Consult the SCS undergraduate concentrations website (https://www.cs.cmu.edu/undergraduate-concentrations/) for information about these concentrations as they are approved. For SCS students, consult with your academic advisor for more information about available concentrations and requirements.

- Algorithms and Complexity
- Computational Biology
- Computer Graphics
- Computer Systems
- Human-Computer Interaction
- Language Technologies
- Machine Learning
- Principles of Programming Languages
- Robotics
- Security and Privacy
- Software Engineering

Algorithms and Complexity Concentration

This concentration is available to SCS students only.

Ryan O'Donnell, *Concentration Director*
Location: GHC 7213

Amy Weis, *Concentration Coordinator*
Location: GHC 4115

The goal of the Algorithms and Complexity concentration is to give SCS students a deep background in the theory of computation as it relates to algorithms and computational complexity. The expectation is that students who complete this concentration will have the background to pursue topics at the PhD level at any top program in the country. Furthermore we expect the reasoning skills gained as part of this concentration could be a significant help in a wide variety of positions in industry.

The concentration is designed to be reasonably flexible covering a wide area of topics within the area of algorithms and complexity. This includes central topics within the area such as complexity theory, and algorithms, but also includes theory as used in areas such as Computational Geometry, Graph Theory, Cryptography, Machine Learning, Algorithms for Large Data, Error Correcting Codes, and Parallel Algorithms.

Common themes of all courses covered by the concentration are the following:

- Clearly defined formalisms of the subject matter.
- A substantial component involving rigorous mathematical analysis, including proofs.
- Abstracting away from specific applications to a more general context.
- Relating algorithms and/or complexity of computation to a variety of complexity measures such as time, space, communication, or information content.

Any given course does not have to exclusively cover these themes and can, for example, also cover experimental aspects of algorithms, or examples applied to quite specific applications.

Learning Objectives

We do not expect students to have high proficiency in all the examples listed, but to gain at least some proficiency from each category.

- The ability to take a loosely defined problem and clearly pose it as a well defined problem specification.
- The understanding of several advanced algorithms beyond what is covered in the core.
- The appreciation a variety of models for bounding resources, such as information theory, space complexity, parallel complexity, communication complexity, proof complexity, query complexity, and hardness of approximation.
- The ability to understand and apply a variety of advanced algorithmic techniques and proof techniques, such as Lovasz Local Lemma, Johnson Lindenstrauss, Chernoff Bounds, sparsification, expanders, probabilistic method, regret bounds, spectral graph theory, fixed parameter tractability and semi-indefinite programming.
- The ability to recognize flaws in ill-formed proofs.
- The ability to formulate new questions about the field.

Prerequisites

The following courses must be completed before the concentration can be completed:

15-210	Parallel and Sequential Data Structures and Algorithms	12
15-251	Great Ideas in Theoretical Computer Science	12
15-259	Probability and Computing	12
or 21-325	Probability	
or 36-218	Probability Theory for Computer Scientists	
15-451	Algorithm Design and Analysis	12

It is expected that all students will start the concentration after having finished all but 15-451.

Course Requirements

The curriculum consists of one required course and at least three elective courses. The three elective courses must sum to at least 30 units. The elective courses will vary from year to year.

Required:

15-455	Undergraduate Complexity Theory	9

Electives (at least three courses with a total of 30 units or more):

10-422	Foundations of Learning, Game Theory, and Their Connections	12
15-354	Computational Discrete Mathematics	12
15-356	Introduction to Cryptography	12
15-458	Discrete Differential Geometry	12
15-459	Undergraduate Quantum Computation	9
15-751	CS Theory Toolkit	12
21-301	Combinatorics	9
21-484	Graph Theory	9
Special permission required:		
47-834	Linear Programming	6
47-835	Network Optimization I	6
47-836	Network Optimization II	6
Other graduate-level courses as approved by the concentration director		

Students can apply one semester of a senior honors research thesis or research-based independent study in a topic related to this concentration, as approved by the concentration director/advisor, as one of the elective courses for this concentration. This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units toward the concentration and can count for at most one elective.

The choice of available elective courses will be posted prior to registration each semester.

Double Counting

The concentration will require that 3 courses (at least 27 units) are not double counted with any other requirements of any Major, Minor, or other concentration the student is pursuing.

Advising and Management

Courses in the list of electives will be approved by the director on a yearly basis under consultation of the algorithms and complexity group (to help evaluate the relevance of the courses) and the CS Program Director (to help flag any logistical issues). Any special requests by a student for counting a course out of the list, will go to the director. The director will also approve any research units.

Students interested in this concentration should contact the concentration director for an initial advising consultation.

Computational Biology Concentration

This concentration is available to SCS students only.

Phillip Compeau, *Concentration Director*
Location: GHC 7403

Tara Seman, *Concentration Coordinator*
Location: GHC 7414

The general goal of the Computational Biology Concentration is to provide foundational coursework in computational biology that will allow undergraduate students in the Carnegie Mellon University School of Computer Science to start building a skillset useful for understanding many of the modern technologies developed by researchers as well as companies in the biotech and biomedical arenas.

This concentration consists of four core courses providing breadth in computational biology across laboratory methods, machine learning, genomics, and modeling of biological systems, as well as one elective that allows students to complete depth coursework in an area of interest, including undergraduate research.

Learning Objectives

Students will, by way of completing this concentration:

- model biological systems at the molecular and cellular levels using a variety of approaches;
- generate their own high throughput molecular biology data in a laboratory setting, and apply computational techniques to analyze the data they generate;
- transform hazy biological problems involving genomic data into well-defined computational problems, design algorithms to solve these problems, and adapt them to biological data;
- explore additional coursework of interest in genomics, biological research automation, biological image analysis, or computational biology research.

This concentration also provides students completing a computational degree other than the major in computational biology (http://www.cbd.cmu.edu/education/bs-in-computational-biology/) with the opportunity to make a transition toward a career in computational biology. We have compiled information on over 250 companies working on computational biology into a unique web resource for students both inside and outside of Carnegie Mellon (http://careers.cbd.cmu.edu (http://careers.cbd.cmu.edu/)). These companies work on diverse topics from the automation of biological research to drug discovery to wearable medical devices to genetic diagnostics. Increasingly, when we interact with these companies, they want computationally minded candidates with as much knowledge of standard approaches in computational biology as possible.

Prerequisites

Note that not all of the prerequisites below are required to take every course in this concentration (for example, 02-251 does not have any of the pre-requisites below), but these courses are required to complete all of the required coursework and should be completed early within this concentration.

15-122	Principles of Imperative Computation	12
15-151	Mathematical Foundations for Computer Science	12
15-210	Parallel and Sequential Data Structures and Algorithms	12
21-241	Matrices and Linear Transformations	11
36-218	Probability Theory for Computer Scientists	9

Further, the following two courses are not technically required as prerequisites to the courses in this concentration, but they are strongly suggested prerequisites because they provide students with helpful surveys of fundamental topics in biology and computational biology.

02-251	Great Ideas in Computational Biology	12
03-151	Honors Modern Biology	10
or 03-121	Modern Biology	

Requirements

Five courses in total are required for this concentration. The following four courses are required as part of a central core of coursework; they consist of three computational biology courses as well as an introductory machine learning course, which today is fundamental for even an introductory understanding of the field.

		Units
02-261	Quantitative Cell and Molecular Biology Laboratory (03-343, Experimental Techniques in Molecular Biology, may be taken if 02-261 is not offered)	Var.
02-510	Computational Genomics	12
02-512	Computational Methods for Biological Modeling and Simulation	9
10-315	Introduction to Machine Learning (SCS Majors)	12

In addition to these four courses above, one elective course is required. Any 02-listed (Computational Biology Department) undergraduate course of at least 9 units at the 300-level or above may satisfy this requirement; graduate courses may be applied to this category with permission. The Computational Biology Department is growing quickly, but at the time of writing, the courses that are regularly offered by the department that would satisfy this requirement are the following:

02-317	Algorithms in Nature	9
02-319	Genomics and Epigenetics of the Brain	9
02-425	Computational Methods for Proteogenomics and Metabolomics	9
02-450	Automation of Scientific Research	9
02-499	Independent Study in Computational Biology	Var.
02-500	Undergraduate Research in Computational Biology (03-441/03-541 may be taken if 02-500 is not offered)	Var.
02-514	String Algorithms	12
02-515	Advanced Topics in Computational Genomics	12
02-518	Computational Medicine	12

Students can apply one semester of a senior honors research thesis or research-based independent study in a topic related to this concentration, as approved by the concentration director/advisor, as the elective course for this concentration. This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units toward the concentration and can count for at most one elective.

Double Counting

At most two courses can double count with all program requirements for majors, minors and other concentrations being pursued by the student. Courses used as free electives for a major are not considered double counted.

Accordingly, this concentration is expressly closed to majors and additional majors in computational biology.

CS and AI majors completing this concentration are encouraged to double-count 10-315 as well as 02-261 as their lab science course. Suggested prerequisites 03-151 and 02-251 also count as requirements for these degrees (as a Science & Engineering course and CS Domains course, respectively).

Advising and Management

The day-to-day management of this concentration (including declaration of the concentration, exception requests, overseeing student audits, advising, etc.) is handled by Phillip Compeau, Assistant Department Head in the Computational Biology Department. Administrative support for the concentration is provided by Samantha Mudrinich. Curricular organization and annual review will be managed by the Computational Biology Undergraduate Review Committee.

SCS students interested in this concentration should set up an appointment with Phillip Compeau for a brief interview.

Computer Graphics Concentration

This concentration is available to SCS students only.

Nancy Pollard, *Concentration Director*
Location: EDSH 227

Amy Weis, *Concentration Coordinator*
Location: GHC 4115

The SCS Computer Graphics Concentration provides an opportunity for SCS undergraduate students at Carnegie Mellon to learn Computer Graphics foundations and specialties from a variety of application and research areas. Students gain a broad view of Computer Graphics in an introductory course and in-depth experience from a choice of topic areas, including the option of independent research. Courses include computational photography, computer games, computer animation, computational geometry, and physics-based rendering. This concentration provides an excellent introduction to the area for students considering industry and the opportunity for
research experience for those considering graduate study.

Learning Objectives

Students completing this concentration will be able to demonstrate the following skills
and learning:

- Create geometric representations for objects and natural phenomena.
- Develop software systems that work with these representations to capture, manipulate, and create artistic and real-world scenes.
- Discuss the pros and cons of alternative models of light transport.
- Develop software systems that utilize these models to create graphical images.
- State the key principles of animation and computer game development.
- Work with kinematic and physically simulated representations of motion to create animations of characters and natural phenomena.
- List key features of camera design, including for the modern camera.
- Work with images and video to perform common operations or generate new creative content.
- Execute common mathematical operations of computer graphics, including geometric transformations, projections, sampling algorithms, modeling of physical processes, optimization, and behavior-based modeling.
- Produce event-driven programs of moderate to large size with constantly evolving graphical / visual display.
- Sketch the layout of a typical massively parallel graphics processing unit (GPU).
- Write software to program the GPU for real-time graphics tasks.

Prerequisites

The following courses must be completed before the concentration can be completed:

15-213	Introduction to Computer Systems	12
21-241	Matrices and Linear Transformations	11

It is expected that all students will start the concentration after having finished all but 15-451.

Course Requirements

The curriculum consists of one required course and at least three elective courses. The three elective courses must sum to at least 30 units. The elective courses will vary from year to year.

Required Course:		
15-362	Computer Graphics	12

Electives (at least three courses with a total of 30 units or more):		
15-365	Experimental Animation	12
15-418	Parallel Computer Architecture and Programming	12
15-456	Computational Geometry	9
15-458	Discrete Differential Geometry	12
15-463	Computational Photography	12
15-464	Technical Animation	12
15-465	Animation Art and Technology	12
15-466	Computer Game Programming	12
15-468	Physics-Based Rendering	12
15-469	Special Topic: Visual Computing Systems	12
15-472	Real-Time Graphics	12
Special permission required:		
16-726	Learning-based Image Synthesis	12
16-823	Physics-based Methods in Vision (Appearance Modeling)	12

Students can apply one semester of a senior honors research thesis or research-based independent study in a topic related to this concentration, as approved by the concentration director/advisor, as one of the elective courses for this concentration. This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units toward the concentration and can count for at most one elective.

RELATION TO OTHER PROGRAMS

The Computer Graphics Concentration overlaps slightly in course offerings of the IDeATE minors in Game Design and Animation and Special Effects, and interested students may also want to investigate these minors. What distinguishes the Computer Graphics Concentration is its focus on the fundamental theory, algorithms, and systems that are relevant to graphics. As such, this is an ideal choice for students who wish to get more in-depth, e.g., in preparation for graduate study or a career in Computer Graphics research.

Other courses to be aware of include:

- 21-344 Numerical Linear Algebra
- 10-725 Convex Optimization

Although they are not a core part of the concentration, these can be valuable courses for additional preparation for the mathematics that runs throughout computer graphics, as well as to prepare for future research and exploration in the field.

Double Counting

At most one course taken for the concentration may be double counted towards any
major, minor or other concentration being pursued by the student. No other double
counting is permitted.

Computer Systems Concentration

This concentration is available to SCS students only.

Brian Railing, *Concentration Director and Advisor*
Location: GHC 6005

Amy Weis, *Concentration Coordinator*
Location: GHC 4115

The goal of the Computer Systems concentration is to give students a broad background in the practical understanding of designing and building systems. Students who complete this concentration are expected to be able to both pursue topics at the Ph.D. level at top programs, as well as industry work, either applying these concepts or directly working within the areas of kernel development, compiler improvements, designing distributed systems, et cetera.

The concentration is designed to be flexible in covering the wide area of systems topics. Two courses from the Computer Science major's “systems” constrained elective are required (List A below). The other courses come from a larger list of related courses (List B below). A limited amount of research credit can count toward the requirements.

Typically, systems courses include three aspects:

- A systems course educates students about how a class of computer systems works, both at a conceptual level and in practice. This includes the study of concrete problems faced in building a particular class of systems and successful solutions to these problems.
- Systems courses address how properties of modern hardware (e.g., processors, net- works, storage hierarchies) influence the design and implementation of a class of soft- ware systems. This typically includes reasoning about concurrency, and understanding and measuring performance.

- To solidify the key systems organization principles, there is a significant project/system implementation aspect to the course, both to reinforce understanding of how these systems work, and to learn system building skills (i.e., not just programming, but also design, debugging, testing, etc.). The size of the programming tasks is course dependent, but a significant fraction of the course grade (e.g., at least 40%) is derived from project work.

Learning Objectives

Students completing this concentration will be able to demonstrate the following skills and learning:

- Students will be able to design, develop and deploy large computer systems and justify their design decisions.
- Students will synthesize the interaction and tradeoffs between different layers and components in computer systems.
- Students will demonstrate debugging expertise on complex and diverse bugs and issues during software development.
- Students will recognize diverse granularities of parallelism, apply them toward solving problems, and implement solutions that achieve correct execution while accounting for reliability, fault tolerance, performance, security, and scalability.

Prerequisites

All students will start the concentration after having finished 15-213 Introduction to Computer Systems (or its cross-listed equivalents) with a C or better, as 15-213 is a prerequisite either directly or indirectly for all courses in the concentration.

Course Requirements

The curriculum will consist of at least four courses: two courses from List A and at least two elective courses from List B. The courses taken from list A and B must sum to at least 51 units. The courses in List A will follow the Systems constrained elective list as part of the degree requirements for a B.S. in Computer Science. The elective courses on List B may vary from year to year, with a plan to review these requirements every three years.

List A (select two):

15-410	Operating System Design and Implementation	15
15-411	Compiler Design	15
15-418	Parallel Computer Architecture and Programming	12
15-440	Distributed Systems	12
15-441	Networking and the Internet	12
15-445	Database Systems	12

List B (select at least two):

Anything from List A, plus...		
15-319	Cloud Computing	12
15-330	Introduction to Computer Security	12
15-346	Computer Architecture: Design and Simulation	12
15-348	Embedded Systems	9
15-412	Operating System Practicum	Var.
15-415	Database Applications	12
17-422	Building User-Focused Sensing Systems	12
18-341	Logic Design and Verification	12
18-344	Computer Systems and the Hardware-Software Interface	12
18-349	Introduction to Embedded Systems	12
18-447	Introduction to Computer Architecture	12
Special permission required for:		
15-719	Advanced Cloud Computing	12
Other graduate-level courses in CSD as approved by the concentration director		

Students can apply one semester of a senior honors research thesis or research-based independent study in a topic related to this concentration, as approved by the concentration director/advisor, as one of the elective courses for this concentration in list B. This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units toward the concentration and can count for at most one elective.

Double Counting

The concentration will require that 3 courses (at least 27 units) are not double counted with any other requirements of any major, minor, or other concentration.

Advising and Management

The courses on the list of electives will be reviewed yearly by the concentration advisor through consultation with the Systems group (to help evaluate the relevance of the courses) and the CS Program Director (to help flag any logistical issues). Any special requests by a student for counting a course outside of the list will go to the concentration advisor. The concentration advisor will also approve any research units.

Students interested in this concentration should set up an initial advising consultation with the concentration advisor.

Human-Computer Interaction Concentration

This concentration is available to SCS students only.

Haiyi Zhu, *Undergraduate Director*
Email: haiyiz@andrew.cmu.edu

Amelia Baisley, *Concentration Manager*
Location: Newell-Simon Hall 3526B

In this concentration, students learn techniques, processes, principles, and theory of Human-Computer Interaction (HCI). This interdisciplinary field aims at understanding how interactions with digital technologies and services can augment what humans do. It also aims at understanding what design, prototyping, and evaluation processes lead to innovative digital technologies and services that fulfill human needs. The concentration enhances what is learned in the SCS majors by addressing how digital products and services can be designed and evaluated so they benefit individuals, small groups, organizations, larger networks, and societies. It is synergistic with SCS majors in that envisioning, designing, and implementing innovative digital interactions benefit from superior technical skill. The concentration consists of 5 courses (2 required courses and 3 electives).

The concentration helps prepare students for jobs as technically-skilled specialists in design and development of interactive systems. The concentration will give students a broader perspective on how technologies impact humans, which may help them move faster into product management positions. It also lays a foundation for graduate study in the field of Human-Computer Interaction.

Learning Objectives

Students will learn skills and methods for:

- Eliciting and understanding human objectives, preferences, and needs through qualitative and quantitative methods for data collection and analysis
- Generating and imagining possible solutions and design concepts that involve human/technology partnerships
- Basic visual design, including typography, grids, color and the use of images
- Design of interactive systems, experiences, and technologies
- Developing and evaluating interactive prototypes as a way of iteratively refining designs
- Evaluating interactive technologies to assess and improve their functioning through data-driven redesign, including discount and empirical evaluation methods

Students will also learn about:

- Digital technologies, including, possibly, web and mobile platforms, conversational technologies, wearable computing, gadgets, digital fabrication, virtual reality and mixed reality
- Human psychology, regarding individuals, groups, organizations, societies, and cultures, as it relates to interactions with digital products and services

Prerequisites

For this concentration, students should have completed the following courses prior to starting the concentration:

15-122	Principles of Imperative Computation	12
15-150	Principles of Functional Programming	12

Course Requirements

The following requirements are for students entering Fall 2024.

Students in an SCS major wanting to complete a concentration in HCI must complete 5 courses, namely, 2 required courses and 3 electives.

Required courses (2 courses)

05-391	Designing Human Centered Software	12
05-360	Interaction Design Fundamentals	12

Electives (3 courses)

1. At least one of the electives must have strong technical content and must be selected from the following list:

05-318	Human AI Interaction	12
05-333	Gadgets, Sensors and Activity Recognition in HCI	12
05-434	Machine Learning in Practice	12
05-499	Special Topics in HCI	12
05-839	Interactive Data Science	12
10-315	Introduction to Machine Learning (SCS Majors)	12
11-411	Natural Language Processing	12
15-237	Special Topic: Cross-Platform Mobile Web Apps	12
15-281	Artificial Intelligence: Representation and Problem Solving	12
15-365	Experimental Animation	12
15-388	Practical Data Science	9
15-462	Computer Graphics	12
15-464	Technical Animation	12
15-466	Computer Game Programming	12
15-494	Cognitive Robotics: The Future of Robot Toys	12
16-467	Introduction to Human Robot Interaction	12
17-422	Building User-Focused Sensing Systems	12
17-428	Machine Learning and Sensing	12
17-437	Web Application Development	12
17-537	Artificial Intelligence Methods for Social Good	9
Other courses as approved by the concentration director		

2. At least one of the electives must have strong design content and must be selected from the following list:

05-361	Advanced Interaction Design	12
05-291	Learning Media Design	12
05-315	Persuasive Design	12
05-317	Design of Artificial Intelligence Products	12
05-418	Design Educational Games	12
05-452	Service Design	12
05-470	Digital Service Innovation	12
*Some (but not all) special topics classes (05-499) might also count towards the design elective requirement. Please consult with an HCI undergraduate advisor.		

3. The remaining elective must be a course in HCI offered by the Human-Computer Interaction Institute, meaning it has a 05 number, or be included in the pre-approved list of electives maintained on the HCII website: https://hcii.cmu.edu/academics/hci-undergrad/electives (https://hcii.cmu.edu/academics/hci-undergrad/electives/)

Other courses may be approved as HCI electives on a case-by-case basis by the HCII Undergraduate Director.

Students can apply one semester of a senior thesis or research-based independent study (05-589) in a topic related to this concentration, as approved by the concentration director/advisor, as an elective courses for this concentration. This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units towards the concentration and can count for at most one elective.

Double Counting

At most 2 courses can be double counted with any major, minor or other concentration being pursued by the student.

ADVISING AND MANAGEMENT

Management will fall on the HCII Undergraduate Director and the HCII Academic Program Manager. The requirements for the courses will be reviewed annually by the HCII Curriculum Committee, in consultation with the URC.

Students in the HCI concentration will be advised by the HCII Undergraduate Director and/or the HCII Academic Program Manager, who also oversee and direct the HCI additional major and the HCI minor.

SCS students interested in this concentration should contact the HCII Academic Program Manager for an initial advising consultation.

Language Technologies

This concentration is available to SCS Students only.

Carolyn P Rose, Concentration Director/Advisor
Location: 5515 Gates Hillman Center
cp3a@andrew.cmu.edu

Introduction

With the recent advances in Large Language Models (LLMs), Human language technologies have become an increasingly central component not only of the field of computer science, but also a suite of key enabling technologies for work in every field. The work of our LTI faculty is impacting the human-critical fields of Education, Medicine, Law, and Finance. Just as a few examples, Dialog systems/chatbots, Information retrieval in many forms, machine translation and speech technologies are used daily by the general public. The LTI prepares students for this world by offering a minor that gives you the opportunity to not only learn about language technologies, but to also apply that knowledge through a directed project and prepares you for lucrative career options, either in this field or just about any other.

Students in our SCS Undergraduate Concentration have the opportunity to build on their undergraduate program requirements not only by learning more about this burgeoning field but also have the opportunity to do hands-on project work directed by one of our world famous faculty. Please feel free to reach out to Undergraduate Program Director Carolyn Rose if you would like to talk about this concentration.

Learning Objectives

Students should be able to...

- Apply the principles of phonetics, morphology, morphosyntax, syntactic formalisms, discourse analysis and pragmatics and sociolinguistics to analyze, describe and discuss languages that they do not normally speak.
- Implement algorithms for organizing and searching large text collections through data mining or building text-based search engines.
- Process natural language input computationally to create automated, intelligent systems to perform language translation, implement question answering, build conversation agents, and query databases using natural interfaces.
- Develop systems that recognize human speech and synthesize human speech.
- Describe the limitations of speech and language analysis systems to pick the most appropriate tools and techniques for the given problem.
- Apply principles in language technologies to a research problem or study to advance the state of the art in this field.

Course Requirements

The Language Technologies Concentration requires that SCS students complete one core course and their choice of three elective courses of at least 9 units each. The electives can be chosen from a specific set of stand-alone courses. In addition to the four courses, students are required to do an undergraduate research project for at least 9 units or choose an additional elective to complete their concentration.

PREREQUISITES

15-122	Principles of Imperative Computation	12
15-150	Principles of Functional Programming	12

Strongly Recommended:

21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
15-259	Probability and Computing	12
or 21-325	Probability	

or 36-218	Probability Theory for Computer Scientists	
or 36-225	Introduction to Probability Theory	

Core Course (12 units)

Students must take the core course below:

11-324	Human Language for Artificial Intelligence	12

Electives (minimum of 27 units)

Students must complete 3 electives from the following list of courses for a minimum of 27 units.

11-344	Machine Learning in Practice	12
11-411	Natural Language Processing	12
11-422	Grammar Formalisims	12
11-423	ConLanging: Lrng. Ling. & Lang Tech via Constru Artif. Lang.	12
11-424	Subword Modeling	12
11-441	Machine Learning with Graphs	9
11-442	Search Engines	9
11-485	Introduction to Deep Learning	9
11-492	Speech Technology for Conversational AI	12
11-667	Large Language Models Methods and Application	12
11-711	Advanced Natural Language Processing	12
11-737	Multilingual Natural Language Processing.	12
11-751	Speech Recognition and Understanding	12
11-776	Multimodal Affective Computing	12
11-777	Multimodal Machine Learning	12
80-180	Nature of Language: An Introduction to Linguistics	9

Research or Additional Elective (MINIMUM OF 9 UNITS)

Students can apply one semester of a senior honors research thesis or research-based independent study in a topic related to this concentration, as approved by the concentration director/advisor, as one of the elective courses for this concentration. This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units toward the concentration and can count for at most one elective. Students who opt not to do research may take an additional elective from the list above.

Double Counting

Courses being used to satisfy the requirements for the Language Technologies Concentration may not be counted towards another minor or concentration. 11-324 Human Language for Artificial Intelligence and 80-180 Nature of Language: An Introduction to Linguistics are the only courses that may be double counted with any other major or minor. All other courses used toward the concentration cannot be counted toward any requirement other than free electives.

Advising

SCS students interested in the concentration in language technologies must apply for admission no later than September 30 of their senior year. An admission decision will usually be made within one month. Students may petition the LTI undergraduate program director to be admitted to the concentration earlier or later in their undergraduate careers. To apply, contact the program's director.

Management

A student working towards the Language Technologies Concentration will select a Language Technologies faculty member as an Advisor with the assistance of the Director. There is also a Language Technologies Concentration Program Coordinator who is a staff member in the Language Technologies Institute. Curriculum changes to this concentration will be reviewed by the Undergraduate Review Committee for approval.

Machine Learning Concentration

This concentration is available to SCS students only.

Matt Gormley, *Concentration Director/Advisor*
Laura Winter, *Concentration Coordinator*
ml-concentration@cs.cmu.edu (ml-minor@cs.cmu.edu)
https://www.ml.cmu.edu/academics/ml-concentration.html

Machine learning and statistical methods are increasingly used in many application areas including natural language processing, speech, vision, robotics, and computational biology. The Concentration in Machine Learning allows undergraduates to learn about the core principles of this field. The Concentration requires five courses (two core courses and three electives) from the School of Computer Science (SCS) and the Department of Statistics & Data Science. The electives primarily focus on core machine learning skills that could be broadly applicable to either industry or graduate work. A CS Senior Honors Thesis or two semesters of Senior Research may be used to satisfy part of the electives requirement, which could provide excellent research experience for students interested in pursuing a PhD.

Learning Objectives

Upon completion of this concentration, students should be able to:

- Formulate real-world problems involving data such that they can be solved by machine learning
- Implement and analyze existing learning algorithms
- Employ probability, statistics, calculus, linear algebra, and optimization in order to develop new predictive models or learning methods
- Select and apply an appropriate supervised learning algorithm for problems of different kinds, including classification, regression, structured prediction, clustering, and representation learning
- Describe the the formal properties of models and algorithms for learning and explain the practical implications of those results
- Compare and contrast different paradigms for learning

Prerequisites

The following courses are expected to be completed before the Core courses in the ML Concentration:

15-122	Principles of Imperative Computation	12
15-151	Mathematical Foundations for Computer Science	12
or 21-127	Concepts of Mathematics	
or 21-128	Mathematical Concepts and Proofs	
36-235	Probability and Statistical Inference I	9
or 36-218	Probability Theory for Computer Scientists	
or 36-219	Probability Theory and Random Processes	
or 36-225	Introduction to Probability Theory	
or 15-259	Probability and Computing	
or 21-235	Mathematical Studies Analysis I	

Course Requirements

The ML Concentration requires that students complete two core courses and their choice of three elective courses of at least 9 units each. The electives can be through a combination of coursework in Machine Learning and optionally senior research.

Core - 2 Courses:

Students must take two core courses, each being at least 9 units:

10-315	Introduction to Machine Learning (SCS Majors)	12
Plus one of:		
10-403	Deep Reinforcement Learning & Control	12
or 10-405	Machine Learning with Large Datasets (Undergraduate)	
or 10-414	Deep Learning Systems: Algorithms and Implementation	
or 10-417	Intermediate Deep Learning	
or 10-418	Machine Learning for Structured Data	
or 10-422	Foundations of Learning, Game Theory, and Their Connections	

Electives - 3 Courses:

Students need to take three courses from the following list, each being at least 9 units. Students may substitute one of these courses with one semester of an SCS Senior Honors Thesis or equivalent senior research credit.

10-403	Deep Reinforcement Learning & Control	12
or 10-703	Deep Reinforcement Learning & Control	
10-405	Machine Learning with Large Datasets (Undergraduate)	12
or 10-605	Machine Learning with Large Datasets	
or 10-745	Scalability in Machine Learning	

10-414	Deep Learning Systems: Algorithms and Implementation	12
10-417	Intermediate Deep Learning	12
or 11-485	Introduction to Deep Learning	
or 10-707	Advanced Deep Learning	
10-418	Machine Learning for Structured Data	12
or 10-618	Machine Learning for Structured Data	
or 10-708	Probabilistic Graphical Models	
10-422	Foundations of Learning, Game Theory, and Their Connections	12
10-423	Generative AI	12
10-425	Introduction to Convex Optimization	12
or 10-725	Convex Optimization	
10-613	Machine Learning Ethics and Society	12
10-777	Historical Advances in Machine Learning	12
36-401	Modern Regression	9

Important Notes:

- To avoid excessive overlap in covered material, at most one of the core Deep Learning courses may be used to fulfill concentration course requirements: 10-417, 10-617, 11-485, 10-707. In general, students are discouraged from taking more than one of these.
- 15-281 Artificial Intelligence: Representation and Problem Solving covers several topics (i.e. reinforcement learning and Bayesian networks) that are complementary to 10-315. While not part of the ML Concentration curriculum, this course is also one to consider.
- Students should note that some of these elective courses (those at the 600-level and higher) are primarily aimed at graduate students, and so should make sure that they are adequately prepared for them before enrolling. Graduate-level cross-listings of these courses can also be used for the ML Concentration, if the student is adequately prepared for the more advanced version and the home department approves the student's registration.
- Please be aware that not all graduate-level courses in the Machine Learning Department may be used as electives. In particular, 10-606/10-607 Computational Foundations for Machine Learning may not be used as electives for the Machine Learning Concentration.

SCS Senior Honors Thesis

The SCS Senior Honors Thesis consists of 36 units of academic credit for this work. Up to 12 units may be counted towards the ML Concentration. Students must consult with the Computer Science Department for information about the SCS Senior Honors Thesis. Once both student and advisor agree upon a project, the student should submit a one-page research proposal to the Machine Learning Concentration Director to confirm that the project will count for the Machine Learning Concentration.

Senior Research

Senior Research consists of 2 semesters of 10-500 Senior Research Project, totaling 24 units. Up to 12 units may be counted towards the ML Concentration.

The research must be a year-long senior project, supervised or co-supervised by a Machine Learning Core Faculty member. It is almost always conducted as two semester-long projects, and must be done in senior year. Interested students should contact the faculty they wish to advise them to discuss the research project, before the semester in which research will take place.

Once both student and advisor agree upon a project, the student should submit a one-page research proposal to the Machine Learning Concentration Director to confirm that the project will count for the Machine Learning Concentration.

The student should email the ML Minor Director a brief update (two paragraphs) on their progress at the end of the Fall semester, and will present the work at the Meeting of the Minds (https://www.cmu.edu/uro/MoM/) and submit a year-end write-up to the Minor Director at the end of Senior year.

Double Counting

At least 3 courses (each being at least 9 units) must be used for only the Machine Learning Concentration, not for any other major, minor, or concentration. (These double counting restrictions apply specifically to the Core Courses and the Electives. Prerequisites may be counted towards other majors, minors, and concentrations and do not count towards the 3 courses that must be used for only the Machine Learning Concentration.)

Advising and Management

The ML Concentration Director will hold advising office hours leading up to registration week each semester. In addition, the ML Concentration Program Coordinator will hold regular office hours to address general questions. All office hours will be detailed on the ML Concentration website.

SCS Students interested in pursuing this concentration should contact Matt Gormley (ml-concentration@cs.cmu.edu (ml-minor@cs.cmu.edu)) for an initial advising consultation.

Principles of Programming Languages Concentration

This concentration is available to SCS students only.

Robert Harper, *Concentration Director and Advisor*
Location: GHC 9229

Amy Weis, *Concentration Coordinator*
Location: GHC 4115

Programming languages play a central role in computer science. All programs are written in a language, and it is obvious that some are better than others, at least for some purposes. The constant demand for new languages reflects the changing demands for constructing reliable and maintainable software systems. Academic research in programming language principles has led to numerous advances in language design, language implementation, and program verification intended to meet these changing expectations through the development of a rigorous theory of programming languages.

Carnegie Mellon is a recognized leader in programming languages, characterized by a strong emphasis on the centrality of type theory, a consolidation of ideas in mathematical semantics, programming logics, and programming language design and implementation. The purpose of the PoPL concentration is to teach the comprehensive view of the field that has been developed here over many decades. Type theory teaches how to define a language, and how to show that it is well-defined, free of internal contradictions. It teaches the mathematical foundations for abstraction and modularity, concepts that are fundamental to building maintainable systems. It teaches how to use a rigorous language definition as the basis for building a compiler that correctly implements the definition, and provides the tools necessary to achieve it. It teaches the logical foundations of program development, how to precisely specify the intended behavior of a program, and how to use machine tools to verify that a program meets those expectations. It gives precise meaning to language concepts, relating them to one another, and distinguishing concepts that are often confused or conflated. It teaches how to specify and verify the resource usage of a program (such as its sequential and parallel time and space complexity) without resorting to a model of how it is implemented on a machine; it supports using actual code, rather than pseudo-code, for defining and analyzing algorithms.

The PoPL concentration is of value to a broad range of students. For the practically minded it will provide the foundation for structuring and validating programs, using type systems or more advanced forms of specification. For the theoretically minded it will provide the foundation for understanding the close relationship between specification and programs on one hand and mathematical conjecture and proof on the other. The elegance of the PoPL lies in their unification of these two perspectives: the theory applies directly to the practice, and the practice informs the theory.

Learning Objectives

The PoPL concentration is characterized by a collection of learning outcomes that it seeks to achieve. These may be summarized by the knowledge that students may expect to gain by concentrating in the area. By their choice of electives each student will choose an emphasis within the area; the required courses ensure that this includes at least the first five objectives:

- Specify the concrete and abstract syntax of a programming language, including a precise specification of the binding and scope of declarations.
- Define the static semantics (compile-time constraints) of a programming language using typing judgments, and how to state and prove that it properly defined.
- Define the dynamics semantics (run-time behavior) of a language using operational and denotational methods.
- Verify rigorously that the statics and dynamics of a language are coherent, a property commonly called type safety.
- Understand the propositions-as-types principle, which relates programs to proofs and specifications to theorems, and know how to apply it in language design and program verification.

- Formulate type and assertion languages for specifying the behavior of a program, and how to verify that a program satisfies such a specification.
- Specify the cost (sequential and parallel time and space complexity) for a program written in a precisely defined language, and how to verify that a given program meets stated cost bounds.
- Use software tools to verify both the properties of languages and the specifications of programs written in well-defined languages.
- Use the static and dynamic semantics of a language to derive a compiler for it that complies with these definitions, and how to use types and verification tools to ensure compiler correctness.
- Relate a language definition to its implementation, both in terms of the run-time structures required, but also to validate abstract cost measures in an implementation.

REQUIREMENTS

This concentration requires two courses along with two additional electives.

Required Course:

15-312	Foundations of Programming Languages	12

Electives (complete three of the following):

15-311	Logic and Mechanized Reasoning	9
15-316	Software Foundations of Security and Privacy	9
15-317	Constructive Logic	9
15-414	Bug Catching: Automated Program Verification	9
15-417	HOT Compilation	12
At the time of this edit, the description of 15-413 was not yet updated in the system. It will be offered as Advanced Topics in Programming Languages beginning in S25, and will count as an elective. Also, many graduate-level Programming Languages course(s), with prior permission of the concentration advisor and the course instructor(s).		

Students can apply one semester of a senior honors research thesis or research-based independent study in a topic related to this concentration, as approved by the concentration director/advisor, as one of the elective courses for this concentration. This research should be supervised by a member of the Principles of Programming faculty in the Computer Science Department. This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units toward the concentration and can count for at most one elective.

Transfer of credit for courses taken outside of Carnegie Mellon University toward this concentration will not be allowed.

Double Counting

15-312 may be double counted towards any major, minor or other concentration being pursued by the student. No other double counting is permitted.

Advising and Management

Participation in this concentration is supervised by the concentration coordinator in cooperation with the students academic advisor, course instructors, and, as appropriate, thesis supervisor. The current advisor is Robert Harper. Content for this concentration will be reviewed yearly by the Principles of Programming faculty in the Computer Science Department.

Students interested in pursuing this concentration should contact Robert Harper for an initial advising consultation.

Robotics Concentration

This concentration is available to SCS students only.

Cameron Riviere, *Concentration Director/Advisor*
Location: NSH 3205

Samantha Bridge, *Concentration Administrator*

The SCS Robotics Concentration provides an opportunity for SCS undergraduate students at Carnegie Mellon to learn the principles and practices of robotics through theoretical studies and hands-on experience with robots. Students initially learn the basics of robotics in an introductory robotics overview course. Additional required courses teach control systems and robotic kinematics. Students also choose from a wide selection of electives in mobile systems, machine learning, computer vision, cognition and cognitive science, or computer graphics. Students have a unique opportunity to undertake independent research projects, working under the guidance of Robotics Institute faculty members; this provides an excellent introduction to robotics practice, for those considering industry and research for those considering graduate studies.

Learning Objectives

Students completing this concentration will be able to demonstrate the following skills and learning:

- construct robots which are driven by a microcontroller through several projects, with each project reinforcing the basic principles of: vision, motion planning, mobile mechanisms, kinematics, inverse kinematics, and sensing
- apply feedback control theory to the development of robotic systems, including the principles of classical linear control theory, linear state-space methods, nonlinear systems theory, and elementary control using computer learning techniques
- program a robot arm using the principles of kinematics and dynamics: transformations, forward kinematics, inverse kinematics, differential kinematics (Jacobians), manipulability, and the basic equations of motion
- apply related fields of computing to the construction and testing of robotic solutions: machine learning, AI, graphics and computer vision, cognitive science and learning models, cyber-physical and embedded systems
- work effectively in a team include computer and mechanical engineers to solve challenging robotics problems

Prerequisites

Successful candidates for the Robotics Minor will have prerequisite knowledge of C language, basic programming skills, and familiarity with basic algorithms. Students can gain this knowledge by taking 15-122 Principles of Imperative Computation.

The probability course can be taken concurrently with the concentration requirements. Depending on specific electives chosen, additional prerequisites may be required (e.g. 21-259).

Course Requirements

The Robotics Concentration requires that students complete three core courses and their choice of two elective courses of at least 9 units each. The electives can be chosen from a specific set of stand-alone courses. Students can opt to do an undergraduate research project as one of their electives.

Required core courses (36 units)

One of the following courses:		
16-311	Introduction to Robotics	12
16-280	General Robotic Systems	12
plus the following two courses:		
16-299	Introduction to Feedback Control Systems	12
16-384	Robot Kinematics and Dynamics	12

Electives

Students must complete 2 electives from the following list of courses for a minimum of 18 units. At least one of the two electives courses must be from the Robotics Institute (16-xxx). A maximum of 12 units of research (16-597) can be used toward this requirement.

Two general robotics electives	**Units**
16-3xx and 16-4xx are pre-approved. Elective coursework outside of the Robotics Institute must be approved by the RI Undergraduate Program Director prior to course enrollment.	**24**

Note: Graduate level Robotics courses may be used to meet the elective requirement with permission from the Concentration Advisor. Graduate level Mechanical Engineering and Electrical and Computer Engineering courses that are relevant to robotics may be used to meet the elective requirement with permission from the Concentration Advisor.

Students can apply one semester of a senior honors research thesis or research-based independent study in a topic related to this concentration, as approved by the concentration director/advisor, as one of the elective courses for this concentration. This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units toward the concentration and can count for at most one elective.

Double Counting

Courses being used to satisfy the requirements for the Robotics Concentration may not be counted towards another minor or concentration. A minimum of 27 units must be completed that is not double counted with any other program. This allows a maximum of 2 courses that can double count with other programs.

Advising and Management

The Robotics Concentration will always have a Robotics faculty member as its Advisor. There will also be a Robotics Concentration Administrator who will track progress for any SCS student pursuing this concentration. Curriculum changes will be discussed with the Robotics Institute faculty and SCS academic deans.

Students interested in this concentration should set up an initial advising consultation with the Concentration Advisor to assess interest and preparation.

Security & Privacy Concentration (SCS)

This concentration is available to SCS students only.
(ECE students should consult their department for an equivalent concentration.)

Lujo Bauer, *Concentration Director and Advisor*
Location: CIC 2203

In a world where data breaches and cyber-attacks are ever-present, the need for technologists who have a solid understanding of the principles that underlie strong security and privacy practices is greater than ever.

The Security & Privacy concentration is designed to expose students to the key facets of and concerns about computer security and privacy that drive practice, research, and legislation. On completing the curriculum, students are well prepared to continue developing their interests in security or privacy through graduate study; to take jobs in security or privacy that will provide further training in applicable areas; and to be informed participants in public and other processes that shape how organizations and society develop to meet new challenges related to computer security or privacy.

Learning Objectives

After completing this concentration, students should:

- Understand how to reason about the adversary in computer systems.
- Be familiar with common security vulnerabilities, from buffer overflows and return oriented programming to cross-site scripting, and widely deployed defenses against these vulnerabilities.
- Be familiar with and understand how to apply the basic concepts in cryptography and secure system design and analysis.
- Understand the key properties of commonly used cryptographic primitives and properties commonly desired of cryptographic protocols.
- Be familiar with current and upcoming research directions in secure system design, software analysis, and cryptography.
- Be familiar with the breadth of concerns and topics relevant to computer security and privacy, ranging from technical topics to ethics, regulation, usability, and economics.
- Be familiar with the key concepts in privacy, ranging from conceptions of privacy to privacy algorithms to regulation and policy.
- Gain a more in-depth understanding of one “context” area: usable security and privacy, or policy.

Prerequisites

Students interested in pursuing this concentration should have the following courses completed before starting the concentration:

15-151	Mathematical Foundations for Computer Science	12
15-213	Introduction to Computer Systems	12
15-251	Great Ideas in Theoretical Computer Science	12

Curriculum

A distinguishing feature of this field is the ubiquitous need to consider an adversary, and the resulting interplay between attack and defense that routinely advances both theory and practice. In order to understand widely-deployed defensive techniques and secure-by-design approaches, students must also understand the attacks that motivate them and the “adversarial mindset” that leads to new forms of attack. The curriculum is designed around this principle.

Students in the Security & Privacy concentration take courses that cover the basic principles *(Introduction and Basics Course Area)*, the underlying theory *(Theoretical Foundations Course Area)*, and the practical application *(System Design Course Area)* of security and privacy. Additionally, students are required to select a course which covers either usability or policy *(Context Course Area)*. Finally, students will be required to explore a topic of their choosing within security and privacy in depth *(Depth Course Area)*.

Requirements (5 courses, minimum 48 units):

Introduction/Portal Entry course		Units
15-330	Introduction to Computer Security	12

Crosslisted courses allowed.

Theoretical Foundations course (choose one option):		Units
15-356	Introduction to Cryptography	12
or both:		
17-731	Foundations of Privacy	12
18-733	Applied Cryptography	12

Crosslisted courses allowed.

System Design course (choose one):		Units
15-316	Software Foundations of Security and Privacy	9
18-335	Secure Software Systems	12

Context Course (select one):		Units
17-334	Usable Privacy and Security	9
or one of:		
17-333	Privacy Policy, Law, and Technology	9
17-731	Foundations of Privacy (not available if used for Theoretical Foundations requirement)	12

Depth Course (complete one option below):		Units
Option 1: Complete an elective course from the below list of approved electives, at least 9 units		9
Option 2: Complete an additional course from the prior categories		9
Option 3: Complete at least 9 units of Independent Study - this option must be pre-approved by your primary advisor as well as the Concentration Director, and an appropriate faculty advisor and study plan submitted.		9
Approved Elective List:		
11-488	Concepts in Digital Multimedia and Cyber Forensics	12
14-795	AI Applications in Information Security	12
14-828	Browser Security	12
14-809	Introduction to Cyber Intelligence	12
14-814	Wireless Network Security	12
14-819	Introduction to Software Reverse-Engineering	12
14-822	Host-Based Forensics	12
14-823	Network Forensics	12
14-829	Mobile and IoT Security	12
15-435	Foundations of Blockchains	12
17-303	Cryptocurrencies, Blockchains and Applications	9
17-735	Engineering Privacy in Software	12
17-880	Algorithms for Private Data Analysis	12
18-334	Network Security	12
18-632	Introduction to Hardware Security	12
18-636	Browser Security	12

Crosslisted courses allowed.

Students can apply one semester of a senior honors research thesis or research-based independent study in a topic related to this concentration, as approved by the concentration director/advisor, as one of the elective courses for this concentration (see option 3 above). This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units toward the concentration and can count for at most one elective.

Anti-requisites

When two (or more) courses overlap significantly in the material they cover, only one can count toward the security and privacy concentration. An example pair is 15-316 Software Foundations of Security and Privacy and 18-335 Secure Software Systems. Another excluded pair is 15-356 Introduction to Cryptography and 18-733 Applied Cryptography. Other such anti-requisites may occur; please consult the concentration director when scheduling courses.

Excluded Courses

Some security and privacy courses may not be counted towards concentration requirements. These courses all serve specific important different purposes, but do not fit into the concentration as currently designed. For example, 17-331 is more suitable for students who are interested in a broader single-course introduction to information security, but has too much overlap with the concentration's required intro course to be able to count toward the concentration. For other excluded courses, please consult the concentration website.

Double Counting

Only two of the courses that are counted toward concentration requirements can also be counted towards core course requirements of other majors and minors being pursued by the student. SCS or ECE General Education Requirements are not included in this double-counting limit.

Advising and Management

The concentration is open to all undergraduates in the School of Computer Science. There is no formal admissions process. Students intending to pursue the concentration should contact the concentration coordinator to register their intention. Curriculum for the concentration will be reviewed by the coordinator annually in consultation with faculty in supporting departments.

Software Engineering Concentration

This concentration is available to SCS students only.

Michael Hilton, *Concentration Director and Advisor*
Location: Wean Hall 5122

Effectively building modern software systems at scale requires not just programming skills, but also engineering skills. These skills include the ability to interact effectively with customers to gather the requirements for a system in a precise way; to develop a design that resolves competing quality attributes; to make tradeoffs among schedule, cost, features, and quality to maximize value to stakeholders; to work effectively with other engineers; and to assure the quality of the delivered software system. We hear regularly from industry that these skills are crucial to them, and that they are interested in students with a strong software engineering background.

Learning Objectives

The software engineering concentration is designed to teach the fundamental tools, techniques, and processes of software engineering. Through internships and a mentored project experience, students gain an understanding of the issues of scale and complexity that motivate software engineering tools and techniques. The core curriculum includes material both on engineering the software product and on the process, teamwork, and management skills that are essential to successful engineering. Graduates of the program should have the technical, process, and teamwork skills to be immediately productive in a mature engineering organization.

Prerequisites

SCS students should have completed the following courses before completing this concentration:

17-214	Principles of Software Construction: Objects, Design, and Concurrency	12
or 15-214	Principles of Software Construction: Objects, Design, and Concurrency	

Course Requirements

Overall, the concentration requires five (5) courses and an internship. One of the five courses consists of a 6-credit course that serves as a writing workshop in which the student reflects upon and integrates the lessons of the internship.

Required Courses (complete all of the following):

17-313	Foundations of Software Engineering	12
or 15-313	Foundations of Software Engineering	
17-413	Software Engineering Practicum	12
or 15-413	SEE 17-413 Software Engineering Practicum	

Electives (complete each category):

Domain-Independent Elective course or mini sequence focused on technical software engineering material (minimum 9 units required):

At least 9 units total.		
15-414	Bug Catching: Automated Program Verification and Testing	9
17-355	Program Analysis	12
17-356	Software Engineering for Startups	12
17-480	API Design and Implementation	12
17-653	Managing Software Development (prerequisite 17-413 or an internship)	6
17-423	Designing Large-scale Software Systems	12
Methods Elective (take both 6-unit mini courses)		
17-614	Formal Methods	6
17-624	Advanced Formal Methods	6
Requirements Elective: Design & Marketing (take two 6-unit mini courses)		
17-612	Business and Marketing Strategy	6
Take either:		
17-626	Requirements for Information Systems	6
17-627	Requirements for Embedded Systems	6
Managing Development (take two 6-unit mini courses)		
17-622	Agile Methods	6
Another mini course of your choice from within this larger list.		
Quality Engineering (take two 6-unit mini courses)		
17-443	Quality Management	6
or		
17-623	Quality Assurance	6
17-731	Foundations of Privacy	12

Crosslisted courses allowed.

Additional courses may count with prior approval by the concentration director.

Computer Science in Society & Industry Elective: a course addressing problems related to existing and emerging technologies and their associated social, political, legal, business, and organizational contexts (minimum 9 units required):

15-390	Entrepreneurship for Computer Science	9
17-200	Ethical Dilemmas and Policy Issues in Computing	9
70-311	Organizational Behavior	9
17-331	Information Security and Privacy	12
17-333	Privacy Policy, Law, and Technology	9
17-334	Usable Privacy and Security	9
19-403	Policies of Wireless Systems	12
70-471	Supply Chain Management	9
17-562	Law of Computer Technology	9
17-781	Mobile and IoT Computing Services	12
17-801	Dynamic Network Analysis	12
17-821	Computational Modeling of Complex Socio-Technical Systems	12
88-341	Organizational Communication	9

Crosslisted courses allowed.

See concentration website for additional course options; additional courses may be counted if prior-approval is given by the Concentration Director.

Students can apply one semester of a senior honors research thesis or research-based independent study in a topic related to this concentration, as approved by the concentration director/advisor, as one of the elective courses for this concentration. This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units toward the concentration and can count for at most one elective. Consult with the concentration director on what elective can be replaced in this option.

Internship and Reflection

The concentration requires a software engineering internship of a minimum of 8 full-time weeks in an industrial setting (i.e., integrated into a team and exposed to industry pressures). The student may work in development, management, quality assurance, or other relevant positions. Students should confirm with the director that an internship is appropriate, but internships that fulfill the criteria will be accepted after the fact. Students must further complete:

17-415	Software Engineering Reflection	6

Double Counting

No more than two of the courses used to fulfill the concentration requirements may be counted towards any other degree or concentration. SCS General Education requirements do not count towards this restriction.

Advising and Management

The concentration coordinator is responsible for academic advising, handling exceptions and updating the curriculum each year, in consultation with faculty in the Institute for Software Research.

Students who are interested in pursuing this concentration should contact the concentration coordinator for an initial advising consultation.

School of Computer Science Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

Software Societal Systems Courses

08-200 Ethics and Policy Issues in Computing

Spring: 9 units
In this course, students will study the social impacts of computing technology and systems. The course will provide a brief introduction to ethics and to the new and difficult ethical questions modern computing technology presents us with. It will focus on a number of areas in which computers and information technology are having an impact on society including data privacy, social media, and autonomous technologies.

08-722 Data Structures for Application Programmers

Fall and Spring: 6 units
This course is an introduction to Data Structures and a few fundamental algorithms for students with some prior programming experience (functions, loops and arrays mainly in Java). It covers the conceptual and implementation views of some common data structures and algorithms. It also goes over the Java Collections (such as List, ArrayList, LinkedList, Set, HashSet, TreeSet, Map, HashMap, TreeMap, PriorityQueue) to solidify the understanding of the data structures. There is an introduction to the analysis of algorithms that operate on them. Following learning-by-doing methodology, there will be many repetitions of writing code and reviews of the items covered in lectures. Students are required to be familiar with Java Programming before taking this course. Those who are not are encouraged to take 08-671 in mini 1 before taking this course. Students are required to have a reasonably modern laptop computer on which install the Java software used for this course.

SCS Interdisciplinary Courses

07-070 Teaching Techniques for Computer Science

Fall and Spring: 2 units
This course is a broad introduction to teaching techniques and DEI issues in the context of computer science education. It is targeted to first-time undergraduate and graduate SCS TAs, with the goal of providing instruction, hands-on practice, and feedback to TAs to improve their instructional proficiency.

07-090 Artificial Intelligence Practicum

All Semesters: 3 units
This course is for Artificial Intelligence students who wish to have an internship experience as part of their curriculum. Students are required to write a one-page summary statement prior to registration that explains how their internship connects with their AI curriculum, specifically on how it uses material they have learned as well as prepares them for future courses. Near the end of the internship, students will be required to submit a reflection paper that describes the work they did in more detail, including lessons learned about the work experience and how they utilized their AI education to work effectively. International students should consult with the Office of International Education for appropriate paperwork and additional requirements before registration. Units earned count toward the total required units necessary for degree completion; students should speak with an academic advisor for details. This course may be taken at most 3 times for a total of 9 units maximum. Students normally register for this course for use during the summer semester.

07-120 Introduction to Software Construction

Fall and Spring: 6 units
Writing software can be very challenging. While software is often written to solve difficult problems, or implement complex algorithms, there are also challenges in the writing of software itself. In this course, students will learn the software construction skills that will help them throughout their career, both as students, and beyond. Students should expect to learn how to decompose an assignment/problem into subtasks, how to track their progress using milestones, evaluating sub regions of code for correctness, as well as finding and fixing faults in code. Students should expect to participate in a variety of in class activities, as well as work on a project implementing the skills they are learning in class.
Prerequisite: 15-112

07-128 First Year Immigration Course

Fall: 3 units
The First Year Immigration Course is taken by first-semester School of Computer Science students on the Pittsburgh campus. The course is designed to acquaint incoming students with computer science at CMU. Talks range from historical perspectives in the field to descriptions of the cutting edge research being conducted in the School of Computer Science. Enrollment is limited to SCS First Year students ONLY.

07-129 Freshmen Immigration Course

Fall: 3 units
The Freshman Immigration Course is taken by first-semester Computer Science majors on the Doha campus. The course is designed to acquaint incoming majors with computer science at CMU. Talks range from historical perspectives in the field to descriptions of the cutting edge research being conducted in the School of Computer Science. Enrollment is limited to SCS Freshmen ONLY.

07-131 Great Practical Ideas for Computer Scientists

Fall: 2 units
SECTION A IS OPEN TO SCS FIRST YEAR STUDENTS ONLY. Throughout your education as a Computer Scientist at Carnegie Mellon, you will take courses on programming, theoretical ideas, logic, systems, etc. As you progress, you will be expected to pick up the so-called "tools of the trade." This course is intended to help you learn what you need to know in a friendly, low-stress, high-support way. We will discuss UNIX, LaTeX, debugging and many other essential tools. Laptop required. Only undergraduate students will be able to enroll in this course.

07-135 Grand Challenge First-Year Seminar: Designing Better Human-AI Futures

Spring: 9 units
This course will explore the societal impacts of artificial intelligence (AI) based decision-making systems, especially focusing on the societal biases they may enhance or reduce. Students will gain a fundamental understanding of how these systems are designed and work, as well as the role of data in mitigating or enhancing biases. The course is multidisciplinary in nature and brings together social scientists, engineers, data scientists, and designers to tackle the grand challenge of dealing with issues of bias and fairness in Human-AI collaborative systems, ranging from the data that is used to train them, to their human creators that are responsible for deciding how they work and get used. Students will investigate policy, technology and societal elements aimed at reducing and mitigating the impact of AI biases that can negatively impact society, especially its vulnerable members.

07-180 Concepts in Artificial Intelligence

Spring: 5 units
The course will introduce students to the main foundational concepts and techniques used in Artificial Intelligence (AI), including representation, heuristic search, probabilistic reasoning, decision making, and machine learning. Concepts will be grounded in a range of real-world applications in which AI is currently used. Students will be introduced to ethical issues surrounding AI, as well as the potential future of a world in which AI is commonplace. Programming and written assignments will enable students to get a feel for how to implement and use AI techniques.
Prerequisites: 15-112 or 15-122

Course Website: https://canvas.cmu.edu/courses/8266 (https://canvas.cmu.edu/courses/8266/)

07-300 Research and Innovation in Computer Science

Fall: 9 units
This Fall course is the first part of a two-course sequence that is designed to help prepare students to invent the future state-of-the-art in the field of computer science. Course topics will include the following: an overview of important things to know about how research and innovation works in the field of computer science; a survey of the current cutting- edge of computer science research, both here at Carnegie Mellon and elsewhere; critical thinking skills when reading research publications that disagree with each other; strategies for coping with open-ended problems; and technical communication skills for computer scientists. Students will also match up with a faculty mentor for a potential Technology Innovation Project (to be performed in the Spring), put together a detailed plan of attack for that project, and start to get up to speed (including background reading, etc.). This course can be used to satisfy the Technical Communications requirement for the CS major.
Prerequisites: 76-101 Min. grade C or 76-102 Min. grade C or (76-106 Min. grade C and 76-107 Min. grade C) or (76-106 Min. grade C and 76-108 Min. grade C) or (76-107 Min. grade C and 76-108 Min. grade C)

07-400 Research Practicum in Computer Science

Spring: 12 units
This Spring course is the second part of a two-course sequence that is designed to help prepare students to invent the future state-of-the-art in the field of computer science. Building directly upon 15-300 (the prerequisite for this course), students will conduct a semester-long independent research project, under the guidance of both the course staff and a faculty project mentor. The course does not meet for lecture or recitations. Instead, the students will spend their time working on their research projects, and will also meet with course staff on a bi-weekly basis to discuss their progress. Students will prepare a written report and a poster presentation at the end of the semester to describe what they have accomplished.
Prerequisites: 07-300 or 15-300

07-590 Independent Study in CS Education (Undergraduate)

Fall and Spring
Description: An independent study course to allow motivated students to work on CS education projects under the supervision of a faculty advisor. Includes the development of a pedagogical study, reading of research papers or texts on CS education, or other suitable activities to learn about the teaching of computer science. Presentation of research or study results required. Independent studies are usually one semester in duration and require prior approval from the faculty advisor and the School of Computer Science.

07-599 SCS Honors Undergraduate Research Thesis

Fall and Spring
Available only to students registered in the CS Senior Research Thesis Program.

07-690 Independent Study in CS Education (Masters)

Fall and Spring
Description: An independent study course to allow motivated students to work on CS education projects under the supervision of a faculty advisor. Includes the development of a pedagogical study, reading of research papers or texts on CS education, or other suitable activities to learn about the teaching of computer science. Presentation of research or study results required. Independent studies are usually one semester in duration and require prior approval from the faculty advisor and the School of Computer Science.

Computational Biology Courses

02-112 Programming for Scientists

Intermittent: 12 units
Provides a practical introduction to programming for students with little or no prior programming experience who are interested in science. Fundamental scientific algorithms will be introduced, and extensive programming assignments will be based on analytical tasks that might be faced by scientists, such as parsing, simulation, and optimization. Principles of good software engineering will also be stressed. The course will introduce students to the Go programming language, an industry-supported, modern programming language, the syntax of which will be covered in depth. Other assignments will be given in other programming languages such as Python and Java to highlight the commonalities and differences between languages. No prior programming experience is assumed, and no biology background is needed. Analytical skills and mathematical maturity are required.

02-180 Great Ideas in Computational Biology I

Spring: 5 units
This course introduces great ideas that have formed the foundation for the recent transformation of life sciences into a fully-fledged computational discipline. Extracting biological understanding from both large and small data sets now requires the use and design of novel algorithms, developed in the field of computational biology. The course is designed as a gateway exposure to computational biology for first-year undergraduates in the School of Computer Science, although it is open to other computationally minded students who are interested in exploring the field. This course is the first in a two-course sequence, showing students fundamental algorithmic techniques that are used in modern biological investigations. This first course focuses on algorithmic techniques for genomics, or the study of DNA, and it addresses questions like and amp;quot;How do we reconstruct the sequence of a genome? and amp;quot;, How do we compare genes and genomes?, and and amp;quot;How can we build evolutionary trees to infer relationships among many species? and amp;quot; Previous exposure to molecular biology is not required.
Prerequisites: (15-112 or 02-201) and (21-128 or 21-127 or 15-151)

02-181 Great Ideas in Computational Biology IIx

Spring: 5 units
This course introduces great ideas that have formed the foundation for the recent transformation of life sciences into a fully-fledged computational discipline. Extracting biological understanding from both large and small data sets now requires the use and design of novel algorithms, developed in the field of computational biology. This course is the second in a two-course sequence, offering a gateway exposure for students showing fundamental algorithmic techniques that are used in modern biological investigations. It is designed for first-year undergraduates in the School of Computer Science, although it is open to other computationally minded students who are interested in exploring the field. Whereas the first course in the sequence focuses on genomics, this second course largely introduces topics outside of DNA, from proteins, to neural networks, to a study of algorithms that nature has evolved to solve problems. Previous exposure to molecular biology is not required. After completion of the course, students will be well equipped to tackle advanced computational challenges in biology.
Prerequisites: (02-201 or 15-112) and (15-151 or 21-127 or 21-128)

02-201 Programming for Scientists

Fall and Spring: 10 units
Provides a practical introduction to programming for students with little or no prior programming experience who are interested in science. Fundamental scientific algorithms will be introduced, and extensive programming assignments will be based on analytical tasks that might be faced by scientists, such as parsing, simulation, and optimization. Principles of good software engineering will also be stressed. The course will introduce students to the Go programming language, an industry-supported, modern programming language, the syntax of which will be covered in depth. Other assignments will be given in other programming languages such as Python and Java to highlight the commonalities and differences between languages. No prior programming experience is assumed, and no biology background is needed. Analytical skills and mathematical maturity are required. Course not open to CS majors.

02-218 Introduction to Computational Medicine

All Semesters: 3 units
This course is an introduction to computational methods relevant to the diagnosis and treatment of human diseases. It is the microcourse version of 02-518, Computational Medicine. The course begins with an introduction to the field of Medicine, and an overview of the primary clinical tasks associated with Computational Medicine (phenotyping; biomarker discovery; predictive modeling). Next, we provide an introduction to several Machine Learning techniques, and how those techniques can be used to perform the clinical tasks. For the remainder of the course, students will be guided through the analysis of a clinical data set to gain experience with these techniques. No prior experience with Medicine, Machine Learning, or computer programming is required. Students will be graded based on quizzes and one homework.

02-223 Personalized Medicine: Understanding Your Own Genome

Fall: 9 units
Do you want to know how to discover the tendencies hidden in your genome? Since the first draft of a human genome sequence became available at the start of this century, the cost of genome sequencing has decreased dramatically. Personal genome sequencing will likely become a routine part of medical exams for patients for prognostic and diagnostic purposes. Personal genome information will also play an increasing role in lifestyle choices, as people take into account their own genetic tendencies. Commercial services such as 23andMe have already taken first steps in this direction. Computational methods for mining large-scale genome data are being developed to unravel the genetic basis of diseases and assist doctors in clinics. This course introduces students to biological, computational, and ethical issues concerning use of personal genome information in health maintenance, medical practice, biomedical research, and policymaking. We focus on practical issues, using individual genome sequences (such as that of Nobel prize winner James Watson) and other population-level genome data. Without requiring any background in biology or CS, we begin with an overview of topics from genetics, molecular biology, stats, and machine learning relevant to the modern personal genome era. We then cover scientific issues such as how to discover your genetic ancestry and how to learn from genomes about migration and evolution of human populations. We discuss medical aspects such as how to predict whether you will develop diseases such as diabetes based on your own genome, how to discover disease-causing genetic mutations, and how genetic information can be used to recommend clinical treatments.

02-250 Introduction to Computational Biology

Spring: 12 units
This class provides a general introduction to computational tools for biology. The course is divided into two halves. The first half covers computational molecular biology and genomics. It examines important sources of biological data, how they are archived and made available to researchers, and what computational tools are available to use them effectively in research. In the process, it covers basic concepts in statistics, mathematics, and computer science needed to effectively use these resources and understand their results. Specific topics covered include sequence data, searching and alignment, structural data, genome sequencing, genome analysis, genetic variation, gene and protein expression, and biological networks and pathways. The second half covers computational cell biology, including biological modeling and image analysis. It includes homework requiring modification of scripts to perform computational analyses. The modeling component includes computer models of population dynamics, biochemical kinetics, cell pathways, and neuron behavior. The imaging component includes the basics of machine vision, morphological image analysis, image classification and image-derived models. The course is taught under two different numbers. The lectures are the same for both but recitations and examinations are separate. 02-250 is intended primarily for computational biology, computer science, statistics or engineering majors at the undergraduate or graduate level who have had prior experience with computer science or programming. 03-250 is intended primarily for biological sciences or biomedical engineering majors who have had limited prior experience with computer science or programming. Students may not take both 02-250 and 03-250 for credit. Prerequisite: (02-201 or 15-110 or 15-112), or permission of the instructors.
Prerequisites: (02-201 or 15-112 or 15-110) and (03-131 or 03-151 or 03-121)

Course Website: http://www.cbd.cmu.edu/education/undergraduate-courses/introduction-to-computational-biology/

02-251 Great Ideas in Computational Biology

Spring: 12 units
This 12-unit course provides an introduction to many of the great ideas that have formed the foundation for the recent transformation of life sciences into a fully-fledged computational discipline. Extracting biological understanding from both large and small data sets now requires the use and design of novel algorithms, developed in the field of computational biology. This gateway course is intended as a first exposure to computational biology for first-year undergraduates in the School of Computer Science, although it is open to other computationally minded 6students who are interested in exploring the field. Students will learn fundamental algorithmic and machine learning techniques that are used in modern biological investigations, including algorithms to process string, graph, and image data. They will use these techniques to answer questions such as "How do we reconstruct the sequence of a genome?", "How do we infer evolutionary relationships among many species?", and "How can we predict each gene's biological role?" on biological data. Previous exposure to molecular biology is not required, as the instructors will provide introductory materials as needed. After completion of the course, students will be well equipped to tackle advanced computational challenges in biology.
Prerequisites: (15-112 or 02-201) and (21-128 or 15-151 or 21-127)

02-261 Quantitative Cell and Molecular Biology Laboratory

Fall and Spring
This is an introductory laboratory-based course designed to teach basic biological laboratory skills used in exploring the quantitative nature of biological systems and the reasoning required for performing research in computational biology. Over the course of the semester, students will design and perform multiple modern experiments and quantitatively analyze the results of these experiments. During this course students will also have an opportunity to use techniques learned during the course to experimentally answer an open question. Designing the experiments will require students to think critically about the biological context of the experiments as well as the necessary controls to ensure interpretable experimental results. During this course students will gain experience in many aspects of scientific research, including: sequencing DNA, designing and performing PCR for a variety of analyses, maintaining cell cultures, taking brightfield and fluorescent microscopy images, developing methods for automated analysis of cell images, communicating results to peers and colleagues. Course Outline: (1) 3-hour lab per week, (1) 1-hour lecture per week.
Prerequisites: 02-201 or 15-112

02-262 Computation and Biology Integrated Research Lab

All Semesters
Modern biological research is heavily interdisciplinary in nature requiring the use of a diverse set of experimental techniques and computational analysis. This course provides students with a modern research experience while training them to communicate and collaborate in an interdisciplinary setting to better prepare them to join the workforce as members of interdisciplinary teams. This will be accomplished by focusing efforts on a real research problem requiring sophisticated experimentation and computation for success. Class time will include both laboratory research time (wet lab and computational) and activities designed to teach and practice communication methods for interdisciplinary teams. Students are expected to have a strong background in biology or computation and an interest in both. Pre-requisites include either (03-117 or 03-124 or 03-343) or (15-112 or equivalent)

02-317 Algorithms in Nature

Intermittent: 9 units
Computer systems and biological processes often rely on networks of interacting entities to reach joint decisions, coordinate and respond to inputs. There are many similarities in the goals and strategies of biological and computational systems which suggest that each can learn from the other. These include the distributed nature of the networks (in biology molecules, cells, or organisms often operate without central control), the ability to successfully handle failures and attacks on a subset of the nodes, modularity and the ability to reuse certain components or sub-networks in multiple applications and the use of stochasticity in biology and randomized algorithms in computer science. In this course we will start by discussing classic biologically motivated algorithms including neural networks (inspired by the brain), genetic algorithms (sequence evolution), non-negative matrix factorization (signal processing in the brain), and search optimization (ant colony formation). We will then continue to discuss more recent bi-directional studies that have relied on biological processes to solve routing and synchronization problems, discover Maximal Independent Sets (MIS), and design robust and fault tolerant networks. In the second part of the class students will read and present new research in this area. Students will also work in groups on a final project in which they develop and test a new biologically inspired algorithm. No prior biological knowledge required.
Prerequisites: 15-210 and 15-251

Course Website: http://www.algorithmsinnature.org

02-319 Genomics and Epigenetics of the Brain

Fall: 9 units
This course will provide an introduction to genomics, epigenetics, and their application to problems in neuroscience. The rapid advances in single cell sequencing and other genomic technologies are revolutionizing how neuroscience research is conducted, providing tools to study how different cell types in the brain produce behavior and contribute to neurological disorders. Analyzing these powerful new datasets requires a foundation in molecular neuroscience as well as key computational biology techniques. In this course, we will cover the biology of epigenetics, how proteins sitting on DNA orchestrate the regulation of genes. In parallel, programming assignments and a project focusing on the analysis of a primary genomic dataset will teach principles of computational biology and their applications to neuroscience. The course material will also serve to demonstrate important concepts in neuroscience, including the diversity of neural cell types, neural plasticity, the role that epigenetics plays in behavior, and how the brain is influenced by neurological and psychiatric disorders. Although the course focuses on neuroscience, the material is accessible and applicable to a wide range of topics in biology.
Prerequisites: (03-121 or 03-151) and (03-221 or 03-220) and (15-112 or 15-121 or 02-201 or 15-110)

02-331 Modeling Evolution

Spring: 12 units
Some of the most serious public health problems we face today, from drug-resistant bacteria, to cancer, all arise from a fundamental property of living systems and #8212; their ability to evolve. Since Darwin's theory of natural selection was first proposed, we have begun to understand how heritable differences in reproductive success drive the adaptation of living systems. This makes it intuitive and tempting to view evolution from an optimization perspective. However, genetic drift, phenotypic trade-offs, constraints, and changing environments, are among the many factors that may limit the optimizing force of natural selection. This tug-of-war between selection and drift, between the forces that produce variation in a population, and the forces suppressing this variation, make evolutionary processes much more complex to model and understand than previously thought. The aim of this class is to provide an introduction into the theoretical formalism necessary to understand how biological systems are shaped by the forces and constraints driving evolutionary dynamics.
Prerequisites: 15-112 and 21-241 and (15-259 or 36-218 or 21-325 or 36-225)

02-402 Computational Biology Seminar

Fall and Spring: 3 units
This course consists of weekly invited presentations on current computational biology research topics by leading scientists. Attendance is mandatory for a passing grade. You must sign in and attend at least 80% of the seminars. See course website for seminar locations. Some will be at the University of Pittsburgh and some will be at Carnegie Mellon.

02-403 Special Topics: Graph Representation Learning in Biology

Intermittent: 12 units
Biological and cellular systems are often modeled as graphs (networks) of interacting elements. This approach has been highly successful owing to the theory, methodology and algorithms that support analysis and learning on graphs. However, recent advances in deep learning techniques have led to a surge in research on graph representation learning. In particular, these advances have led to new state-of-the-art results in biomedicine and healthcare. This course will provide a synthesis and overview of graph representation learning within systems biology and medicine. We will begin with a discussion of the goals of graph representation learning, as well as key methodological foundations in graph theory and network analysis. We next review traditional methods such as topological descriptors, graph kernels, and spectral graph theory. We then introduce techniques for learning node embeddings, including random-walk based methods and applications to knowledge graphs. We finally provide a technical synthesis and introduction to the highly successful graph neural network formalism as well as recent advancements in deep generative models for graphs.
Prerequisites: (02-250 Min. grade C or 03-250 Min. grade C) and 03-121 Min. grade C

02-414 String Algorithms

Intermittent: 12 units
Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous amounts of collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Borrows-Wheeler transform. Applications of these techniques in genomics will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases.
Prerequisites: 15-127 or 15-151 or 21-128

02-421 Algorithms for Computational Structural Biology

Intermittent: 12 units
Some of the most interesting and difficult challenges in computational biology and bioinformatics arise from the determination, manipulation, or exploitation of molecular structures. This course will survey these challenges and present a variety of computational methods for addressing them. Topics will include: molecular dynamics simulations, computer-aided drug design, and computer-aided protein design. The course is appropriate for both students with backgrounds in computer science and those in the life sciences.

02-425 Computational Methods for Proteogenomics and Metabolomics

Spring: 9 units
Proteomics and metabolomics are the large scale study of proteins and metabolites, respectively. In contrast to genomes, proteomes and metabolomes vary with time and the specific stress or conditions an organism is under. Applications of proteomics and metabolomics include determination of protein and metabolite functions (including in immunology and neurobiology) and discovery of biomarkers for disease. These applications require advanced computational methods to analyze experimental measurements, create models from them, and integrate with information from diverse sources. This course specifically covers computational mass spectrometry, structural proteomics, proteogenomics, metabolomics, genome mining and metagenomics.
Prerequisites: 02-250 or 02-604 or 02-251

02-450 Automation of Scientific Research

Spring: 9 units
Automated scientific instruments are used widely in research and engineering. Robots dramatically increase the reproducibility of scientific experiments, and are often cheaper and faster than humans, but are most often used to execute brute-force sweeps over experimental conditions. The result is that many experiments are "wasted" on conditions where the effect could have been predicted. Thus, there is a need for computational techniques capable of selecting the most informative experiments. This course will introduce students to techniques from Artificial Intelligence and Machine Learning for automatically selecting experiments to accelerate the pace of discovery and to reduce the overall cost of research. Real-world applications from Biology, Bioengineering, and Medicine will be studied. Grading will be based on homeworks and two exams. The course is intended to be self-contained, but students should have a basic knowledge of biology, programming, statistics, and machine learning.
Prerequisites: (10-701 or 10-315) and 15-122

02-499 Independent Study in Computational Biology

Fall and Spring
The student will, under the individual guidance of a faculty member, read and digest process papers or a textbook in an advanced area of computational biology not offered by an existing course at Carnegie Mellon. The student will demonstrate their mastery of the material by a combination of one or more of the following: oral discussions with the faculty member; exercises set by the faculty member accompanying the readings; and a written summary synthesizing the material that the student learned. Permission required.

02-500 Undergraduate Research in Computational Biology

Fall and Spring
This course is for undergraduate students who wish to do supervised research for academic credit with a Computational Biology faculty member. Interested students should first contact the Professor with whom they would like to work. If there is mutual interest, the Professor will direct you to the Academic Programs Coordinator who will enroll you in the course. 02-250 is a suggested pre-requisite.

Course Website: https://forms.gle/S1AJX65btkTxwNCw9 (https://forms.gle/S1AJX65btkTxwNCw9/)

02-510 Computational Genomics

Spring: 12 units
Dramatic advances in experimental technology and computational analysis are fundamentally transforming the basic nature and goal of biological research. The emergence of new frontiers in biology, such as evolutionary genomics and systems biology is demanding new methodologies that can confront quantitative issues of substantial computational and mathematical sophistication. From the computational side this course focuses on modern machine learning methodologies for computational problems in molecular biology and genetics, including probabilistic modeling, inference and learning algorithms, data integration, time series analysis, active learning, etc. This course counts as a CSD Applications elective
Prerequisites: 15-122 Min. grade C and (36-235 or 36-218 or 15-259 or 36-225)

02-512 Computational Methods for Biological Modeling and Simulation

Fall: 9 units
This course covers a variety of computational methods important for modeling and simulation of biological systems. It is intended for graduates and advanced undergraduates with either biological or computational backgrounds who are interested in developing computer models and simulations of biological systems. The course will emphasize practical algorithms and algorithm design methods drawn from various disciplines of computer science and applied mathematics that are useful in biological applications. The general topics covered will be models for optimization problems, simulation and sampling, and parameter tuning. Course work will include problem sets with significant programming components and independent or group final projects.
Prerequisites: (15-259 or 36-225 or 36-235 or 36-219 or 21-325 or 36-218 or 36-217) and (21-240 or 21-242 or 21-241) and (02-201 or 15-110 or 15-112) and 21-121

02-514 String Algorithms

Fall: 12 units
Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Burrows-Wheeler transform. Applications of these techniques in biology will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases. No knowledge of biology is assumed, and the topics covered will be of use in other fields involving large collections of strings. Programming proficiency is required.
Prerequisite: 15-251

02-515 Advanced Topics in Computational Genomics

Spring: 12 units
Research in biology and medicine is undergoing a revolution due to the availability of high-throughput technology for probing various aspects of a cell at a genome-wide scale. The next-generation sequencing technology is allowing researchers to inexpensively generate a large volume of genome sequence data. In combination with various other high-throughput techniques for epigenome, transcriptome, and proteome, we have unprecedented opportunities to answer fundamental questions in cell biology and understand the disease processes with the goal of finding treatments in medicine. The challenge in this new genomic era is to develop computational methods for integrating different data types and extracting complex patterns accurately and efficiently from a large volume of data. This course will discuss computational issues arising from high-throughput techniques recently introduced in biology, and cover very recent developments in computational genomics and population genetics, including genome structural variant discovery, association mapping, epigenome analysis, cancer genomics, and transcriptome analysis. The course material will be drawn from very recent literature. Grading will be based on weekly write-ups for ciritiques of the papers to be discussed in the class, class participation, and a final project. It assumes a basic knowledge of machine learning and computational genomics.

02-518 Computational Medicine

Fall: 12 units
Modern medical research increasingly relies on the analysis of large patient datasets to enhance our understanding of human diseases. This course will focus on the computational problems that arise from studies of human diseases and the translation of research to the bedside to improve human health. The topics to be covered include computational strategies for advancing personalized medicine, pharmacogenomics for predicting individual drug responses, metagenomics for learning the role of the microbiome in human health, mining electronic medical records to identify disease phenotypes, and case studies in complex human diseases such as cancer and asthma. We will discuss how machine learning methodologies such as regression, classification, clustering, semi-supervised learning, probabilistic modeling, and time-series modeling are being used to analyze a variety of datasets collected by clinicians. Class sessions will consist of lectures, discussions of papers from the literature, and guest presentations by clinicians and other domain experts. Grading will be based on homework assignments and a project. 02-250 is a suggested pre-requisite.

Course Website: https://sites.google.com/view/computationalmedicine/

02-530 Cell and Systems Modeling

Fall: 12 units
This course will introduce students to the theory and practice of modeling biological systems from the molecular to the organism level with an emphasis on intracellular processes. Topics covered include kinetic and equilibrium descriptions of biological processes, systematic approaches to model building and parameter estimation, analysis of biochemical circuits modeled as differential equations, modeling the effects of noise using stochastic methods, modeling spatial effects, and modeling at higher levels of abstraction or scale using logical or agent-based approaches. A range of biological models and applications will be considered including gene regulatory networks, cell signaling, and cell cycle regulation. Weekly lab sessions will provide students hands-on experience with methods and models presented in class. Course requirements include regular class participation, bi-weekly homework assignments, a take-home exam, and a final project. The course is designed for graduate and upper-level undergraduate students with a wide variety of backgrounds. The course is intended to be self-contained but students may need to do some additional work to gain fluency in core concepts. Students should have a basic knowledge of calculus, differential equations, and chemistry as well as some previous exposure to molecular biology and biochemistry. Experience with programming and numerical computation is useful but not mandatory. Laboratory exercises will use MATLAB as the primary modeling and computational tool augmented by additional software as needed.
Prerequisites: (33-121 or 03-151 or 03-121) and (03-231 or 03-232) and 21-112 and 09-105

02-540 Bioimage Informatics

Intermittent: 12 units
With the rapid advance of bioimaging techniques and fast accumulation of bioimage data, computational bioimage analysis and modeling are playing an increasingly important role in understanding of complex biological systems. The goals of this course are to provide students with the ability to understand a broad set of practical and cutting-edge computational techniques to extract knowledge from bioimages.
Prerequisites: 02-620 or 10-301 or 10-701 or 10-601 or 10-315

02-601 Programming for Scientists

Fall and Spring: 12 units
Provides a practical introduction to programming for students with little previous programming experience who are interested in science. Fundamental scientific algorithms will be introduced, and extensive programming assignments will be based on analytical tasks that might be faced by scientists, such as parsing, simulation, and optimization. Principles of good software engineering will also be stressed. The course will introduce students to the Go programming language, an industry-supported, modern programming language, the syntax of which will be covered in depth. Other assignments may be given in other programming languages to highlight the commonalities and differences between languages. No biology background is needed. Analytical skills, an understanding of programming basics, and mathematical maturity are required. A preparatory self-paced bootcamp on programming basics is provided to students to complete before beginning the course

02-602 Professional Issues for Computational and Automated Scientists

Fall and Spring: 3 units
This course gives Master's in Computational Biology and Master's in Automated Science students the opportunity to develop the professional skills necessary for a successful career in either academia or industry. This course, required in the first semester of both programs, will include assistance with elevator pitches, interview preparation, resume and cover letter writing, networking, and presentation skills. The course will also include opportunities to connect with computational biology professionals as part of industry outreach. The course will meet once a week and is pass/fail only.

02-604 Fundamentals of Bioinformatics

Spring: 12 units
How do we find potentially harmful mutations in your genome? How can we reconstruct the Tree of Life? How do we compare similar genes from different species? These are just three of the many central questions of modern biology that can only be answered using computational approaches. This 12-unit course will delve into some of the fundamental computational ideas used in biology and let students apply existing resources that are used in practice every day by thousands of biologists. The course offers an opportunity for students who possess an introductory programming background to become more experienced coders within a biological setting. As such, it presents a natural next course for students who have completed 02-601.

02-605 Professional Issues in Automated Science

Spring: 3 units
This course gives MS in Automated Science students an opportunity to develop professional skills necessary for a successful career in computational biology. This course will include assistance with resume writing, interview preparation, presentation skills, and job search techniques. This course will also include opportunities to network with computational biology professionals and academic researchers.

02-613 Algorithms and Advanced Data Structures

Fall and Spring: 12 units
The objective of this course is to study algorithms for general computational problems, with a focus on the principles used to design those algorithms. Efficient data structures will be discussed to support these algorithmic concepts. Topics include: Run time analysis, divide-and-conquer algorithms, dynamic programming algorithms, network flow algorithms, linear and integer programming, large-scale search algorithms and heuristics, efficient data storage and query, and NP-completeness. Although this course may have a few programming assignments, it is primarily not a programming course. Instead, it will focus on the design and analysis of algorithms for general classes of problems. This course is not open to CS graduate students who should consider taking 15-651 instead. 02-250 is a suggested prerequisite for undergraduates.

02-614 String Algorithms

Intermittent: 12 units
Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous amounts of collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Borrows-Wheeler transform. Applications of these techniques in genomics will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases.
Prerequisites: 15-151 or 15-127 or 21-128

02-620 Machine Learning for Scientists

Spring: 12 units
With advances in scientific instruments and high-throughput technology, scientific discoveries are increasingly made from analyzing large-scale data generated from experiments or collected from observational studies. Machine learning methods that have been widely used to extract complex patterns from large speech, text, and image data are now being routinely applied to answer scientific questions in biology, bioengineering, and medicine. This course is intended for graduate students interested in learning machine learning methods for scientific data analysis and modeling. It will cover classification and regression techniques such a logistic regression, random forest regression, Gaussian process regression, decision trees, and support vector machines; unsupervised learning methods such as clustering algorithms, mixture models, and hidden Markov models; probabilistic graphical models and deep learning methods; and learning theories such as PAC learning and VC dimension. The course will focus on applications of these methods in genomics and medicine. Programming skills and basic knowledge of linear algebra, probability, statistics are assumed.
Prerequisite: 02-680

02-651 New Technologies and Future Markets

Fall: 12 units
This course focuses on technological trends and how these trends can help shape or disrupt new and existing markets. Students will learn to identify, analyze, and synthesize emerging trends and perform detailed research on how these trends can influence and create markets. By understand the drivers behind these trends students will be able to identify key market opportunity inflection points in biotechnology as well as the relationship between business processes and information technology (IT). Students will also learn to assess some information technologies and the potential of applying them to solve problems and create commercially viable solutions. The course is designed for the student interested in finding new venture opportunities on the cutting edge of technology and finding and evaluating the opportunities for further development. For MS Biotechnology Innovation and Computation students only.
Prerequisite: 11-695

02-654 Biotechnology Enterprise Development

Fall: 12 units
In this course students learn how to develop a biotech start-up, create a Minimum Viable Product (MVP), business model and strategy for the product. Students will learn about business modeling, customer development, customer validation, proposal, product branding, and marketing for their product. The course will require students to spend most time to validate their start up concept and prototypes with potential customers and adapt to critical feedback and revise their respective value propositions accordingly. Students learn to balance technical product development with customer requirements, business strategy and budget constraints. This course provides real world, hands-on learning on what it is like to start a company. Different business modeling will be covered. By understand customer discovery and validation concepts will aid students to effectively modify their original concepts to meet market demands. Student teams will learn how to revise, improve their prototype by the end of the term. This is a fast paced course in which students are expected to spend most of the time outside of the classroom to interact with potential customers to validate, test, verify, and integrate essentials elements for their start-up business proposal. Up to now, students have been learning some technologies and methods for solving problems in the life science industry and build a prototype for their start-up. However, a new venture proposal is not a collection of isolated bits. It should be thorough validated via customer's inputs and market needs to tell a single story of how the venture will reach its end goals. Final deliverable is creation and presentation of a well explicated, business proposal in addition to a product prototype corresponding to the business proposal.
Prerequisites: 02-651 and 11-695

02-680 Essential Mathematics and Statistics for Scientists

Fall: 9 units
This course rigorously introduces fundamental topics in mathematics and statistics to first-year master's students as preparation for more advanced computational coursework. Topics are sampled from information theory, graph theory, proof techniques, phylogenetics, combinatorics, set theory, linear algebra, neural networks, probability distributions and densities, multivariate probability distributions, maximum likelihood estimation, statistical inference, hypothesis testing, Bayesian inference, and stochastic processes. Students completing this course will obtain a broad skillset of mathematical techniques and statistical inference as well as a deep understanding of mathematical proof. They will have the quantitative foundation to immediately step into an introductory master's level machine learning or automation course. This background will also serve students well in advanced courses that apply concepts in machine learning to scientific datasets, such as 02-710 (Computational Genomics) or 02-750 (Automation of Biological Research). The course grade will be computed as the result of homework assignments, midterm tests, and class participation.

02-699 Independent Study in Computational Biology

Fall and Spring
The student will, under the individual guidance of a faculty member, read and digest process papers or a textbook in an advanced area of computational biology not offered by an existing course at Carnegie Mellon. The student will demonstrate their mastery of the material by a combination of one or more of the following: oral discussions with the faculty member; exercises set by the faculty member accompanying the readings; and a written summary synthesizing the material that the student learned. Permission required.

02-700 M.S. Thesis Research

Fall and Spring
This course is for M.S. students who wish to do supervised research for academic credit with a Computational Biology faculty member. Interested students should first contact the Professor with whom they would like to work. If there is mutual interest, the Professor will direct you to the Academic Programs Coordinator, who will enroll you in the course.

Course Website: https://forms.gle/tDKDs1EujvXAApYK7 (https://forms.gle/tDKDs1EujvXAApYK7/)

02-702 Computational Biology Seminar

Fall and Spring: 3 units
This course consists of weekly invited presentations on current computational biology research topics by leading scientists. Attendance is mandatory for a passing grade. You must sign in and attend at least 80 percent of the seminars. See course website for seminar locations. Some will be at the University of Pittsburgh and some will be at Carnegie Mellon.

Course Website: https://www.compbio.cmu.edu/seminar-series/index.html (https://www.compbio.cmu.edu/seminar-series/)

02-703 Special Topics: Graph Representation Learning in Biology

Intermittent: 12 units
Biological and cellular systems are often modeled as graphs (networks) of interacting elements. This approach has been highly successful owing to the theory, methodology and algorithms that support analysis and learning on graphs. However, recent advances in deep learning techniques have led to a surge in research on graph representation learning. In particular, these advances have led to new state-of-the-art results in biomedicine and healthcare. This course will provide a synthesis and overview of graph representation learning within systems biology and medicine. We will begin with a discussion of the goals of graph representation learning, as well as key methodological foundations in graph theory and network analysis. We next review traditional methods such as topological descriptors, graph kernels, and spectral graph theory. We then introduce techniques for learning node embeddings, including random-walk based methods and applications to knowledge graphs. We finally provide a technical synthesis and introduction to the highly successful graph neural network formalism as well as recent advancements in deep generative models for graphs.

02-704 Special Topics: Introduction to Statistical Genetics

Intermittent: 12 units
This course will cover quantitative topics in human statistical genetics, including the HapMap project, linkage disequilibrium, population structure and stratification, natural selection, genome-wide association studies, estimating and partitioning heritability, association testing, statistical fine-mapping, disease gene mapping, expression quantitative trait loci, single-cell genomics, and polygenic risk prediction. The course will emphasize hands-on analysis of large empirical data sets, thus requiring prior experience with a general-purpose high-level programming language such as Python. After taking this course, each student will have the experience and skills to develop and apply statistical methods to population genetic data.
Prerequisites: (02-601 or 15-112) and (02-680 or 36-226 or 36-236 or 15-259 or 15-260 or 36-218)

02-710 Computational Genomics

Spring: 12 units
Dramatic advances in experimental technology and computational analysis are fundamentally transforming the basic nature and goal of biological research. The emergence of new frontiers in biology, such as evolutionary genomics and systems biology is demanding new methodologies that can confront quantitative issues of substantial computational and mathematical sophistication. From the computational side this course focuses on modern machine learning methodologies for computational problems in molecular biology and genetics, including probabilistic modeling, inference and learning algorithms, data integration, time series analysis, active learning, etc. This course counts as a CSD Applications elective

02-711 Computational Molecular Biology and Genomics

Spring: 12 units
An advanced introduction to computational molecular biology, using an applied algorithms approach. The first part of the course will cover established algorithmic methods, including pairwise sequence alignment and dynamic programming, multiple sequence alignment, fast database search heuristics, hidden Markov models for molecular motifs and phylogeny reconstruction. The second part of the course will explore emerging computational problems driven by the newest genomic research. Course work includes four to six problem sets, one midterm and final exam.
Prerequisites: (03-121 or 03-151) and 15-122

02-712 Computational Methods for Biological Modeling and Simulation

Fall: 12 units
This course covers a variety of computational methods important for modeling and simulation of biological systems. It is intended for graduates and advanced undergraduates with either biological or computational backgrounds who are interested in developing computer models and simulations of biological systems. The course will emphasize practical algorithms and algorithm design methods drawn from various disciplines of computer science and applied mathematics that are useful in biological applications. The general topics covered will be models for optimization problems, simulation and sampling, and parameter tuning. Course work will include problem sets with significant programming components and independent or group final projects.
Prerequisites: (02-601 or 15-112 or 15-110) and (15-259 or 21-325 or 36-218 or 36-219 or 02-680 or 36-217 or 36-235 or 36-225)

02-714 String Algorithms

Fall: 12 units
Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Borrows-Wheeler transform. Applications of these techniques in biology will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases. No knowledge of biology is assumed, and the topics covered will be of use in other fields involving large collections of strings. Programming proficiency is required.
Prerequisite: 15-251

02-715 Advanced Topics in Computational Genomics

Spring: 12 units
Research in biology and medicine is undergoing a revolution due to the availability of high-throughput technology for probing various aspects of a cell at a genome-wide scale. The next-generation sequencing technology is allowing researchers to inexpensively generate a large volume of genome sequence data. In combination with various other high-throughput techniques for epigenome, transcriptome, and proteome, we have unprecedented opportunities to answer fundamental questions in cell biology and understand the disease processes with the goal of finding treatments in medicine. The challenge in this new genomic era is to develop computational methods for integrating different data types and extracting complex patterns accurately and efficiently from a large volume of data. This course will discuss computational issues arising from high-throughput techniques recently introduced in biology, and cover very recent developments in computational genomics and population genetics, including genome structural variant discovery, association mapping, epigenome analysis, cancer genomics, and transcriptome analysis. The course material will be drawn from very recent literature. Grading will be based on weekly write-ups for ciritiques of the papers to be discussed in the class, class participation, and a final project. It assumes a basic knowledge of machine learning and computational genomics.

02-717 Algorithms in Nature

Fall: 12 units
Computer systems and biological processes often rely on networks of interacting entities to reach joint decisions, coordinate and respond to inputs. There are many similarities in the goals and strategies of biological and computational systems which suggest that each can learn from the other. These include the distributed nature of the networks (in biology molecules, cells, or organisms often operate without central control), the ability to successfully handle failures and attacks on a subset of the nodes, modularity and the ability to reuse certain components or sub-networks in multiple applications and the use of stochasticity in biology and randomized algorithms in computer science. In this course we will start by discussing classic biologically motivated algorithms including neural networks (inspired by the brain), genetic algorithms (sequence evolution), non-negative matrix factorization (signal processing in the brain), and search optimization (ant colony formation). We will then continue to discuss more recent bi-directional studies that have relied on biological processes to solve routing and synchronization problems, discover Maximal Independent Sets (MIS), and design robust and fault tolerant networks. In the second part of the class students will read and present new research in this area. Students will also work in groups on a final project in which they develop and test a new biologically inspired algorithm. See also: www.algorithmsinnature.org no prior biological knowledge required.

02-718 Computational Medicine

Fall: 12 units
Modern medical research increasingly relies on the analysis of large patient datasets to enhance our understanding of human diseases. This course will focus on the computational problems that arise from studies of human diseases and the translation of research to the bedside to improve human health. The topics to be covered include computational strategies for advancing personalized medicine, pharmacogenomics for predicting individual drug responses, metagenomics for learning the role of the microbiome in human health, mining electronic medical records to identify disease phenotypes, and case studies in complex human diseases such as cancer and asthma. We will discuss how machine learning methodologies such as regression, classification, clustering, semi-supervised learning, probabilistic modeling, and time-series modeling are being used to analyze a variety of datasets collected by clinicians. Class sessions will consist of lectures, discussions of papers from the literature, and guest presentations by clinicians and other domain experts. Grading will be based on homework assignments and a project. 02-250 is a suggested pre-requisite.
Prerequisites: 10-315 or (10-701 and 10-601 and 10-401)

Course Website: https://sites.google.com/view/computationalmedicine/

02-719 Genomics and Epigenetics of the Brain

Fall: 12 units
This course will provide an introduction to genomics, epigenetics, and their application to problems in neuroscience. The rapid advances in single cell sequencing and other genomic technologies are revolutionizing how neuroscience research is conducted, providing tools to study how different cell types in the brain produce behavior and contribute to neurological disorders. Analyzing these powerful new datasets requires a foundation in molecular neuroscience as well as key computational biology techniques. In this course, we will cover the biology of epigenetics, how proteins sitting on DNA orchestrate the regulation of genes. In parallel, programming assignments and a project focusing on the analysis of a primary genomic dataset will teach principles of computational biology and their applications to neuroscience. The course material will also serve to demonstrate important concepts in neuroscience, including the diversity of neural cell types, neural plasticity, the role that epigenetics plays in behavior, and how the brain is influenced by neurological and psychiatric disorders. Although the course focuses on neuroscience, the material is accessible and applicable to a wide range of topics in biology.
Prerequisites: (03-121 or 03-151) and 03-220 and (15-110 or 15-121 or 02-201)

02-721 Algorithms for Computational Structural Biology

Intermittent: 12 units
Some of the most interesting and difficult challenges in computational biology and bioinformatics arise from the determination, manipulation, or exploitation of molecular structures. This course will survey these challenges and present a variety of computational methods for addressing them. Topics will include: molecular dynamics simulations, computer-aided drug design, and computer-aided protein design. The course is appropriate for both students with backgrounds in computer science and those in the life sciences.

02-725 Computational Methods for Proteogenomics and Metabolomics

Spring: 12 units
Proteomics and metabolomics are the large scale study of proteins and metabolites, respectively. In contrast to genomes, proteomes and metabolomes vary with time and the specific stress or conditions an organism is under. Applications of proteomics and metabolomics include determination of protein and metabolite functions (including in immunology and neurobiology) and discovery of biomarkers for disease. These applications require advanced computational methods to analyze experimental measurements, create models from them, and integrate with information from diverse sources. This course specifically covers computational mass spectrometry, structural proteomics, proteogenomics, metabolomics, genome mining and metagenomics.
Prerequisites: 02-250 or 02-251 or 02-604

02-730 Cell and Systems Modeling

Fall: 12 units
This course will introduce students to the theory and practice of modeling biological systems from the molecular to the organism level with an emphasis on intracellular processes. Topics covered include kinetic and equilibrium descriptions of biological processes, systematic approaches to model building and parameter estimation, analysis of biochemical circuits modeled as differential equations, modeling the effects of noise using stochastic methods, modeling spatial effects, and modeling at higher levels of abstraction or scale using logical or agent-based approaches. A range of biological models and applications will be considered including gene regulatory networks, cell signaling, and cell cycle regulation. Weekly lab sessions will provide students hands-on experience with methods and models presented in class. Course requirements include regular class participation, bi-weekly homework assignments, a take-home exam, and a final project. The course is designed for graduate and upper-level undergraduate students with a wide variety of backgrounds. The course is intended to be self-contained but students may need to do some additional work to gain fluency in core concepts. Students should have a basic knowledge of calculus, differential equations, and chemistry as well as some previous exposure to molecular biology and biochemistry. Experience with programming and numerical computation is useful but not mandatory. Laboratory exercises will use MATLAB as the primary modeling and computational tool augmented by additional software as needed. *THIS COURSE WILL BE AT PITT
Prerequisites: (33-121 or 03-121 or 03-151) and (03-231 or 03-232) and 21-112 and 09-105

Course Website: https://sites.google.com/site/cellandsystemsmodeling/

02-731 Modeling Evolution

Spring: 12 units
Some of the most serious public health problems we face today, from drug-resistant bacteria, to cancer, all arise from a fundamental property of living systems and #8212; their ability to evolve. Since Darwin's theory of natural selection was first proposed, we have begun to understand how heritable differences in reproductive success drive the adaptation of living systems. This makes it intuitive and tempting to view evolution from an optimization perspective. However, genetic drift, phenotypic trade-offs, constraints, and changing environments, are among the many factors that may limit the optimizing force of natural selection. This tug-of-war between selection and drift, between the forces that produce variation in a population, and the forces suppressing this variation, make evolutionary processes much more complex to model and understand than previously thought. The aim of this class is to provide an introduction into the theoretical formalism necessary to understand how biological systems are shaped by the forces and constraints driving evolutionary dynamics.
Prerequisites: 15-112 and 21-241 and (36-225 or 15-259 or 36-218 or 21-325)

02-740 Bioimage Informatics

Intermittent: 12 units
With the rapid advance of bioimaging techniques and fast accumulation of bioimage data, computational bioimage analysis and modeling are playing an increasingly important role in understanding of complex biological systems. The goals of this course are to provide students with the ability to understand a broad set of practical and cutting-edge computational techniques to extract knowledge from bioimages.

02-750 Automation of Scientific Research

Spring: 12 units
Automated scientific instruments are used widely in research and engineering. Robots dramatically increase the reproducibility of scientific experiments, and are often cheaper and faster than humans, but are most often used to execute brute-force sweeps over experimental conditions. The result is that many experiments are "wasted" on conditions where the effect could have been predicted. Thus, there is a need for computational techniques capable of selecting the most informative experiments. This course will introduce students to techniques from Artificial Intelligence and Machine Learning for automatically selecting experiments to accelerate the pace of discovery and to reduce the overall cost of research. Real-world applications from Biology, Bioengineering, and Medicine will be studied. Grading will be based on homeworks and two exams. The course is intended to be self-contained, but students should have a basic knowledge of biology, programming, statistics, and machine learning.
Prerequisites: 10-601 or 10-701 or 02-620

02-760 Laboratory Methods for Computational Biologists

Fall and Spring: 9 units
Computational biologists frequently focus on analyzing and modeling large amounts of biological data, often from high-throughput assays or diverse sources. It is therefore critical that students training in computational biology be familiar with the paradigms and methods of experimentation and measurement that lead to the production of these data. This one-semester laboratory course gives students a deeper appreciation of the principles and challenges of biological experimentation. Students learn a range of topics, including experimental design, structural biology, next generation sequencing, genomics, proteomics, bioimaging, and high-content screening. Class sessions are primarily devoted to designing and performing experiments in the lab using the above techniques. Students are required to keep a detailed laboratory notebook of their experiments and summarize their resulting data in written abstracts and oral presentations given in class-hosted lab meetings. With an emphasis on the basics of experimentation and broad views of multiple cutting-edge and high-throughput techniques, this course is appropriate for students who have never taken a traditional undergraduate biology lab course, as well as those who have and are looking for introductory training in more advanced approaches. Grading: Letter grade based on class participation, laboratory notebooks, experimental design assignments, and written and oral presentations. 02-250 is a suggested pre-requisite.

02-761 Laboratory Methods for Automated Biology I

Fall: 12 units
In order to rapidly generate reproducible experimental data, many modern biology labs leverage some form of laboratory automation to execute experiments. In the not so distant future, the use of laboratory automation will continue to increase in the biological lab to the point where many labs will be fully automated. Therefore, it is critical for automation scientists to be familiar with the principles, experimental paradigms, and techniques for automating biological experimentation with an eye toward the fully automated laboratory. In this laboratory course, students will learn about various automatable experimental methods, design of experiments, hardware for preparing samples and executing automated experiments, and software for controlling that hardware. These topics will be taught in lectures as well as through laboratory experience using multi-purpose laboratory robotics. During weekly laboratory time, students will complete and integrate parts of two larger projects. The first project will be focused on liquid handling, plate control, plate reading, and remote control of the automated system based on experimental data. The second project will be focused on the design, implementation, and analysis of a high content screening campaign using fluorescence microscopy, image analysis, and tissue culture methods.

02-762 Laboratory Methods for Automated Biology II

Spring: 12 units
This laboratory course provides a continuation and extension of experiences in 02-761. Instruction will consist of lectures and laboratory experience using multi-purpose laboratory robotics. During weekly laboratory time, students will complete and integrate parts of two larger projects. The first project will be focused on the execution of a molecular biology experiment requiring nucleic acid extraction, library preparation for sequencing, and quality control. The second project will be focused on the implementation and execution of automated methods using active learning techniques to direct the learning of a predictive model for a large experimental space (such as learning the effects of many possible drugs on many possible targets). Grading will be based on lab and project completion and quality.
Prerequisite: 02-761

02-764 Automated Science Capstone II

Spring: 12 units
This course consists of small group projects on development, implementation and/or execution of automated science campaigns in collaboration with industry and/or academic partners. This course may only be taken as part of a continuous sequence with 02-763. Enrollment is only open to M.S. in Automated Science students.

Computer Science Courses

15-050 Study Abroad

All Semesters
Students who are interested in studying abroad should first contact the Office of International Education. More information on Study Abroad is available on OIE's Study Abroad page and at the CS Undergraduate Office.

15-090 Computer Science Practicum

All Semesters: 3 units
This course is for Computer Science students who wish to have an internship experience as part of their curriculum. Students are required to write a one-page summary statement prior to registration that explains how their internship connects with their CS curriculum, specifically on how it uses material they have learned as well as prepares them for future courses. Near the end of the internship, students will be required to submit a reflection paper that describes the work they did in more detail, including lessons learned about the work experience and how they utilized their CS education to work effectively. International students should consult with the Office of International Education for appropriate paperwork and additional requirements before registration. Units earned count toward the total required units necessary for degree completion; students should speak with an academic advisor for details. This course may be taken at most 3 times for a total of 9 units maximum. Students normally register for this course for use during the summer semester.

Course Website: https://csd.cs.cmu.edu/course-profiles/15-090-Computer-Science-Practicum (https://csd.cs.cmu.edu/course-profiles/15-090-Computer-Science-Practicum/)

15-104 Introduction to Computing for Creative Practice

Fall: 10 units
An introduction to fundamental computing principles and programming techniques for creative cultural practices, with special consideration to applications in music, design and the visual arts. Intended for students with little to no prior programming experience, the course develops skills and understanding of text-based programming in a procedural style, including idioms of sequencing, selection, iteration, and recursion. Topics include data organization (arrays, files, trees), interfaces and abstraction (modular software design, using sensor data and software libraries), basic algorithms (searching and sorting), and computational principles (randomness, concurrency, complexity). Intended for students participating in IDeATe courses or minors who have not taken 15-112.

Course Website: https://csd.cs.cmu.edu/course-profiles/15-104-Introduction-to-Computing-for-Creative-Practice (https://csd.cs.cmu.edu/course-profiles/15-104-Introduction-to-Computing-for-Creative-Practice/)

15-106 Introduction to Computing for Data Analysis

Spring: 5 units
[Course Pilot] An introductory course in programming for students in statistics-related disciplines using R. Fundamental data types and data structures: booleans, numbers, characters, vectors, matrices, data frames, and lists. Programming constructs: assignment, conditionals, loops, function calls. Processing data: vectorization, "apply" functions, text processing, plotting tools. Additional topics, time permitting: writing functions, using data files, random number generation and simulation. This course is not for credit for SCS majors.

Course Website: http://www.cs.cmu.edu/~mrmiller/15-106/

15-110 Principles of Computing

All Semesters: 10 units
A course in fundamental computing principles for students with minimal or no computing background. Programming constructs: sequencing, selection, iteration, and recursion. Data organization: arrays and lists. Use of abstraction in computing: data representation, computer organization, computer networks, functional decomposition, and application programming interfaces. Use of computational principles in problem-solving: divide and conquer, randomness, and concurrency. Classification of computational problems based on complexity, non-computable functions, and using heuristics to find reasonable solutions to complex problems. Social, ethical and legal issues associated with the development of new computational artifacts will also be discussed.

Course Website: https://www.cs.cmu.edu/~15110/

15-112 Fundamentals of Programming and Computer Science

All Semesters: 12 units
A technical introduction to the fundamentals of programming with an emphasis on producing clear, robust, and reasonably efficient code using top-down design, informal analysis, and effective testing and debugging. Starting from first principles, we will cover a large subset of the Python programming language, including its standard libraries and programming paradigms. We will also target numerous deployment scenarios, including standalone programs, shell scripts, and web-based applications. This course assumes no prior programming experience. Even so, it is a fast-paced and rigorous preparation for 15-122. Students seeking a more gentle introduction to computer science should consider first taking 15-110. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course.

Course Website: https://www.cs.cmu.edu/~112/

15-121 Introduction to Data Structures

Fall: 10 units
A continuation of the process of program design and analysis for students with some prior programming experience (functions, loops, and arrays, not necessarily in Java). The course reinforces object-oriented programming techniques in Java and covers data aggregates, data structures (e.g., linked lists, stacks, queues, trees, and graphs), and an introduction to the analysis of algorithms that operate on those data structures.
Prerequisite: 15-112

Course Website: http://www.cs.cmu.edu/~mjs/121/index.html (http://www.cs.cmu.edu/~mjs/121/)

15-122 Principles of Imperative Computation

All Semesters: 12 units
For students with a basic understanding of programming (variables, expressions, loops, arrays, functions). Teaches imperative programming and methods for ensuring the correctness of programs. Students will learn the process and concepts needed to go from high-level descriptions of algorithms to correct imperative implementations, with specific application to basic data structures and algorithms. Much of the course will be conducted in a subset of C amenable to verification, with a transition to full C near the end. This course prepares students for 15-213 and 15-210. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course.
Prerequisite: 15-112 Min. grade C

Course Website: http://www.cs.cmu.edu/~15122/home.shtml (http://www.cs.cmu.edu/~15122/home.shtml/)

15-128 Freshman Immigration Course

Fall: 1 unit
The Freshman Immigration Course is taken by first-semester Computer Science majors on the Pittsburgh campus. The course is designed to acquaint incoming majors with computer science at CMU. Talks range from historical perspectives in the field to descriptions of the cutting edge research being conducted in the School of Computer Science. Enrollment is limited to SCS Freshmen ONLY.

15-129 Freshman Immigration II

Fall: 3 units
This course is ONLY offered at Carnegie Mellon in Qatar. Students and instructors will solve different problems each week by searching the Web and other likely places for answers. The problems will be submitted by other faculty who will grade the quality of the answers. Students will learn strategies and techniques for finding information on the Web more efficiently; learn when to start with a search engine, a subject-oriented directory, or other tools; explore and practice using advanced search syntax for major search engines; experience specialized search engines for images, sound, multimedia, newsgroups, and discussion lists as well as subject-specific search engines; discover valuable resources to help keep you up-to-date in this fast-changing environment.

15-131 Great Practical Ideas for Computer Scientists

Fall: 2 units
THIS COURSE IS OPEN TO CS FRESHMAN ONLY. Throughout your education as a Computer Scientist at Carnegie Mellon, you will take courses on programming, theoretical ideas, logic, systems, etc. As you progress, you will be expected to pick up the so-called "tools of the trade." This course is intended to help you learn what you need to know in a friendly, low-stress, high-support way. We will discuss UNIX, LaTeX, debugging and many other essential tools. Laptop required. (Laptops will be available for those without their own laptops.)

Course Website: https://www.cs.cmu.edu/~15131/f17/

15-150 Principles of Functional Programming

All Semesters: 12 units
An introduction to programming based on a "functional" model of computation. The functional model is a natural generalization of algebra in which programs are formulas that describe the output of a computation in terms of its inputs and #8212;-that is, as a function. But instead of being confined to real- or complex-valued functions, the functional model extends the algebraic view to a very rich class of data types, including not only aggregates built up from other types, but also functions themselves as values. This course is an introduction to programming that is focused on the central concepts of function and type. One major theme is the interplay between inductive types, which are built up incrementally; recursive functions, which compute over inductive types by decomposition; and proof by structural induction, which is used to prove the correctness and time complexity of a recursive function. Another major theme is the role of types in structuring large programs into separate modules, and the integration of imperative programming through the introduction of data types whose values may be altered during computation. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course.
Prerequisites: (21-128 Min. grade C or 15-151 Min. grade C or 21-127 Min. grade C) and 15-112 Min. grade C

Course Website: http://www.cs.cmu.edu/~15150/

15-151 Mathematical Foundations for Computer Science

Fall: 12 units
CS majors only This course is offered to incoming Computer Science freshmen and focuses on the fundamental concepts in Mathematics that are of particular interest to Computer Science such as logic, sets,induction, functions, and combinatorics. These topics are used as a context in which students learn to formalize arguments using the methods of mathematical proof. This course uses experimentation and collaboration as ways to gain better understanding of the material. Open to CS freshmen only. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course.
Prerequisite: 21-120

Course Website: https://www.math.cmu.edu/~jmackey/151_128/welcome.html

15-155 The Computational Lens

Spring: 9 units
What is knowable, in principle and in practice? - What does it mean to be intelligent? - Can creativity be automated? - What is the role of randomness in the universe? - How can we achieve provable guarantees of security, privacy, fairness, etc. in various settings? - What does the social network of the world look like? - Do we live in a simulation? Despite their differences, all of these questions are fundamentally about the notion of computation. And all these questions can be put under the following single umbrella: What is computation and how does it shape our understanding of life, science, technology, and society? This course is for anyone interested in these questions and more broadly, anyone interested in the algorithmic lens to tackle hard, foundational problems. Our goal will be to find reliable explanations through modeling and rigorous reasoning. We will discuss great and powerful ideas from the field of theory of computation and see how these ideas shed new light on human reasoning, laws of nature, life, technology, and society.
Prerequisites: 15-112 or 15-110 or 15-104

Course Website: http://computationallens.com

15-181 Demystifying AI

Spring: 9 units
This course will pull back the curtains on artificial intelligence, helping you learn what it is, what it can do, how to use it, how it works, and what can go wrong. This course is designed for students that want to learn about AI and machine learning but don't have the course schedule bandwidth to build up the math and computing background required for full-fledged intro AI and ML courses, such as 15-281 and 10-301. Leveraging high school algebra and basic Python programming skills from 15-110, we'll help you implement key pieces of AI techniques from the nearest neighbor algorithm to simple neural networks. Through in-class activities, weekly recitations, and course assignments, you'll start to learn how to use AI systems, including how to make them "intelligent", what data might be needed, and what can go wrong. Ethical discussions will be woven throughout the course to enable you to think critically about how AI impacts our society.
Prerequisites: 15-112 or 15-110

15-182 Artificial Intelligence for Medicine

Intermittent: 6 units
This course introduces Artificial Intelligence (AI) and its recent applications in medicine for students with no background in computer science. It starts by motivating and defining AI, before folding over to a survey of some of its newest applications to medicine, including diagnosis, prognosis, drug discovery, and recommendations of individualized treatments, to mention just a few. Afterwards, it provides a birds-eye view of some of the major AI techniques, including machine learning, deep neural networks, recommendation systems, ranked retrieval, and probabilistic graphical models. Finally, it concludes with a discussion on some of the concerns related to AI, including ethical issues, job security, society, and healthcare institutions, among others

15-195 Competition Programming I

All Semesters: 5 units
Each year, Carnegie Mellon fields several teams for participation in the ICPC Regional Programming Contest. During many recent years, one of those teams has earned the right to represent Carnegie Mellon at the ICPC World Finals. This course is a vehicle for those who consistently and rigorously train in preparation for the contests to earn course credit for their effort and achievement. Preparation involves the study of algorithms, the practice of programming and debugging, the development of test sets, and the growth of team, communication, and problem solving skills. Neither the course grade nor the number of units earned are dependent on ranking in any contest. Students are not required to earn course credit to participate in practices or to compete in ACM-ICPC events. Students who have not yet taken 15-295 should register for 15-195; only students who have already taken 15-295 should register for 15-295 again.
Prerequisite: 15-122 Min. grade C

15-199 Special Topics: Discovering Logic

Intermittent: 3 units
This course is ONLY offered at Carnegie Mellon in Qatar. This course has the purpose of introducing first-year Computer Science students to elements of formal logic as well as to the historical context in which this discipline developed. As all subsequent courses in the CS curriculum rely on students having mastered basic logical notions and skills, it will test and enhance your preparation, thereby putting you in a better position to succeed in the program. It will also help you understand and appreciate how CS came about since Computer Science grew out of logic. The specific knowledge and skills you will learn in is course include: an enhanced ability to research topics, give presentations and write technical prose, some elementary logic, some historical depth into Computer Science, mathematics and logic itself. This course is open to Computer Science freshmen only.

15-210 Parallel and Sequential Data Structures and Algorithms

Fall and Spring: 12 units
Teaches students about how to design, analyze, and program algorithms and data structures. The course emphasizes parallel algorithms and analysis, and how sequential algorithms can be considered a special case. The course goes into more theoretical content on algorithm analysis than 15-122 and 15-150 while still including a significant programming component and covering a variety of practical applications such as problems in data analysis, graphics, text processing, and the computational sciences. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course. Register for Lecture 1. All students will be waitlisted for Lecture 2 until Lecture 1 is full.
Prerequisites: 15-150 Min. grade C and 15-122 Min. grade C

Course Website: http://www.cs.cmu.edu/~15210/

15-213 Introduction to Computer Systems

All Semesters: 12 units
This course provides a programmer's view of how computer systems execute programs, store information, and communicate. It enables students to become more effective programmers, especially in dealing with issues of performance, portability and robustness. It also serves as a foundation for courses on compilers, networks, operating systems, and computer architecture, where a deeper understanding of systems-level issues is required. Topics covered include: machine-level code and its generation by optimizing compilers, performance evaluation and optimization, computer arithmetic, memory organization and management, networking technology and protocols, and supporting concurrent computation. NOTE FOR GRADUATE STUDENTS: This course is not open to graduate students beginning Spring 2015. Graduate students must register for 15-513 instead.
Prerequisite: 15-122 Min. grade C

Course Website: https://www.cs.cmu.edu/~213/

15-214 Principles of Software Construction: Objects, Design, and Concurrency

Fall and Spring: 12 units
Software engineers today are less likely to design data structures and algorithms from scratch and more likely to build systems from library and framework components. In this course, students engage with concepts related to the construction of software systems at scale, building on their understanding of the basic building blocks of data structures, algorithms, program structures, and computer structures. The course covers technical topics in four areas: (1) concepts of design for complex systems, (2) object oriented programming, (3) static and dynamic analysis for programs, and (4) concurrent and distributed software. Student assignments involve engagement with complex software such as distributed massively multi-player game systems and frameworks for graphical user interaction.
Prerequisites: (15-122 Min. grade C or 15-121 Min. grade C) and (21-127 Min. grade C or 15-151 Min. grade C or 21-128 Min. grade C)

15-217 Logic and Mechanized Reasoning

Fall: 9 units
Symbolic logic is fundamental to computer science, providing a foundation for the theory of programming languages, database theory, AI, knowledge representation, automated reasoning, interactive theorem proving, and formal verification. Formal methods based on logic complement statistical methods and machine learning by providing rules of inference and means of representation with precise semantics. These methods are central to hardware and software verification, and have also been used to solve open problems in mathematics. This course will introduce students to logic on three levels: theory, implementation, and application. It will focus specifically on applications to automated reasoning and interactive theorem proving. We will present the underlying mathematical theory, and students will develop the mathematical skills that are needed to design and reason about logical systems in a rigorous way. We will also show students how to represent logical objects in a functional programming language, Lean, and how to implement fundamental logical algorithms. We will show students how to use contemporary automated reasoning tools, including SAT solvers, SMT solvers, and first-order theorem provers to solve challenging problems. Finally, we will show students how to use Lean as an interactive theorem prover.
Prerequisites: (15-151 Min. grade C or 21-128 Min. grade C or 21-127 Min. grade C) and 15-150 Min. grade C

Course Website: http://www.cs.cmu.edu/~mheule/15217-f21/

15-236 Special Topics: Saving Humanity With Computational Models

Intermittent: 9 units
We live in a complex society and on a complex planet; but we tend to think about the world through simplified models and assumptions. How do we know if our simplified mental models make sense? Computational modeling is an approach to understanding our understanding of the world wherein we write down our mental models as computer code, mix in a bit of real data, and run it to see what we can learn. Models can help us to understand ourselves, the world around us, and how to shape the future. This course will teach the basics of computational modeling through hands-on exercises investigating student-directed topics. We will cover the basics of computational modeling, finding and processing data, visualization, modularity, and interactivity. Students will build a series of models throughout the course, starting with smaller warm-ups and culminating in a final project in which students will work together to create a high-quality model and interactive web-based visualization with the goal of informing public discourse and policymaking. This course is designed for CS sophomores and most "seats" in the course will be reserved for CS sophomores.
Prerequisites: 15-112 Min. grade C and 21-120 Min. grade C

15-237 Special Topic: Cross-Platform Mobile Web Apps

Intermittent: 12 units
An introduction to writing cross-platform mobile web apps. Using a tool chain based on HTML5, CSS3, JavaScript, and a variety of supporting frameworks, we will write apps that are effectively designed both for desktop and mobile browsers, and which can be converted into native apps for Android, iOS, and Windows Phone 7 devices. Additional topics will include designing user interfaces for mobile devices, accessing mobile device API's (such as accelerometer, GPS, compass, or camera), and power management issues. While this course focuses on browser-side technologies, we will briefly explore JavaScript-based server-side technologies (though students should consider 15-437 for extensive treatment of server-side topics). Note that we will not be writing native apps in Objective-C for iOS nor in Java for Android, though we may include some brief exposure to these technologies near the end of the course.
Prerequisite: 15-112 Min. grade C

15-251 Great Ideas in Theoretical Computer Science

Fall and Spring: 12 units
This course is about how to use theoretical ideas to formulate and solve problems in computer science. It integrates mathematical material with general problem solving techniques and computer science applications. Examples are drawn from algorithms, complexity theory, game theory, probability theory, graph theory, automata theory, algebra, cryptography, and combinatorics. Assignments involve both mathematical proofs and programming. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course.
Prerequisites: (15-150 Min. grade C or 15-122 Min. grade C) and (15-151 Min. grade C or 21-127 Min. grade C or 21-128 Min. grade C)

Course Website: http://www.cs.cmu.edu/~15251/

15-259 Probability and Computing

Spring: 12 units
Probability theory is indispensable in computer science today. In areas such as artificial intelligence and computer science theory, probabilistic reasoning and randomization are central. Within networks and systems, probability is used to model uncertainty and queuing latency. This course gives an introduction to probability as it is used in computer science theory and practice, drawing on applications and current research developments as motivation. The course has 3 parts: Part I is an introduction to probability, including discrete and continuous random variables, heavy tails, simulation, Laplace transforms, z-transforms, and applications of generating functions. Part II is an in-depth coverage of concentration inequalities, like the Chernoff bound and SLLN bounds, as well as their use in randomized algorithms. Part III covers Markov chains (both discrete-time and continuous-time) and stochastic processes and their application to queuing systems performance modeling. This is a fast-paced class which will cover more material than the other probability options and will cover it in greater depth.
Prerequisites: 15-251 Min. grade C or 21-228 Min. grade C

15-260 Statistics and Computing

Spring: 3 units
Statistics is essential for a wide range of fields including machine learning, artificial intelligence, bioinformatics, and finance. This mini course presents the fundamental concepts and methods in statistics in six lectures. The course covers key topics in statistical estimation, inference, and prediction. This course is only open to students enrolled in 15-259. Enrollment for 15-260, mini 4, starts around mid semester.
Prerequisites: 21-241 Min. grade C and 21-259 Min. grade C and 15-251 Min. grade C

15-281 Artificial Intelligence: Representation and Problem Solving

Fall and Spring: 12 units
This course is about the theory and practice of Artificial Intelligence. We will study modern techniques for computers to represent task-relevant information and make intelligent (i.e. satisficing or optimal) decisions towards the achievement of goals. The search and problem solving methods are applicable throughout a large range of industrial, civil, medical, financial, robotic, and information systems. We will investigate questions about AI systems such as: how to represent knowledge, how to effectively generate appropriate sequences of actions and how to search among alternatives to find optimal or near-optimal solutions. We will also explore how to deal with uncertainty in the world, how to learn from experience, and how to learn decision rules from data. We expect that by the end of the course students will have a thorough understanding of the algorithmic foundations of AI, how probability and AI are closely interrelated, and how automated agents learn. We also expect students to acquire a strong appreciation of the big-picture aspects of developing fully autonomous intelligent agents. Other lectures will introduce additional aspects of AI, including natural language processing, web-based search engines, industrial applications, autonomous robotics, and economic/game-theoretic decision making.
Prerequisites: 15-122 Min. grade C and (21-240 Min. grade C or 18-202 Min. grade C or 21-241 Min. grade C or 21-254 Min. grade C) and (21-127 Min. grade C or 15-151 Min. grade C or 21-128 Min. grade C)

Course Website: https://www.cs.cmu.edu/~15281/

15-282 Artificial Intelligence for Medicine

Intermittent: 10 units
This course introduces Artificial Intelligence (AI) and its recent applications in medicine for students with only a little background in computer science. It starts by motivating and defining AI, before folding over to a survey of some of its newest applications to medicine, including diagnosis, prognosis, drug discovery, and recommendations of individualized treatments, to mention just a few. Afterwards, it provides a birds-eye view of some of the major AI techniques, including machine learning, deep neural networks, recommendation systems, ranked retrieval, and probabilistic graphical models. Finally, it concludes with a discussion on some of the concerns related to AI, including ethical issues, job security, society, and healthcare institutions, among others. The course comprises a balance of lectures, case studies, live demonstrations of some medical AI applications, problem-solving and amp; programming assignments, and research tasks. The students will be exposed to industry- and research-based perspectives on AI for medicine. In addition, they will learn through a course project the nuances of working with medical data and applying AI models to solve concrete problems in healthcare.
Prerequisite: 15-112 Min. grade C

15-288 Special Topic: Machine Learning in a Nutshell

Fall and Spring: 9 units
THIS COURSE RUNS IN CMU QATAR ONLY. This course is about the application of machine learning (ML) concepts and models to solve challenging real-world problems. The emphasis of the course is on the methodological and practical aspects of designing, implementing, and using ML solutions. Course topics develop around the notion of ML process pipeline, that identifies the multi-staged process of building and deploying an ML solution. An ML pipeline includes: de nition of the problem, objectives, and performance metrics; collection and management of relevant operational data; data wrangling (transforming, cleaning, ltering, scaling); perform feature engineering on the available data in terms of feature selection, feature extraction, feature processing; selection of appropriate ML models based on problem requirements and available data; implementation, application, testing, and evaluation of the selected model(s); deployment of the final ML model. The course tackles all the stages of the ML pipeline, presenting conceptual insights and providing algorithmic and software tools to select and implement effective ways of proceeding and dealing with the challenges of the different stages.
Prerequisite: 15-112 Min. grade C

15-292 History of Computing

Spring: 5 units
This course traces the history of computational devices, pioneers and principles from the early ages through the present. Topics include early computational devices, mechanical computation in the 19th century, events that led to electronic computing advances in the 20th century, the advent of personal computing and the Internet, and the social, legal and ethical impact of modern computational artifacts. This course also includes a history of programming languages, operating systems, processors and computing platforms. Students should have an introductory exposure to programming prior to taking this course.
Prerequisites: (76-108 or 76-106 or 76-101 or 76-102 or 76-107) and (15-112 or 15-122 or 15-150 or 15-110)

15-294 Special Topic: Rapid Prototyping Technologies

Fall and Spring: 5 units
This mini-course introduces students to rapid prototyping technologies with a focus on laser cutting and 3D printing. The course has three components: 1) A survey of rapid prototyping and additive manufacturing technologies, the maker and open source movements, and societal impacts of these technologies; 2) An introduction to the computer science behind these technologies: CAD tools, file formats, slicing algorithms; 3) Hands-on experience with SolidWorks, laser cutting, and 3D printing, culminating in student projects (e.g. artistic creations, functional objects, replicas of famous calculating machines, etc.).
Prerequisites: 15-104 Min. grade C or 15-110 Min. grade C or 15-112 Min. grade C

Course Website: https://www.cs.cmu.edu/afs/cs.cmu.edu/academic/class/15294-f21/

15-295 Competition Programming II

Fall and Spring: 5 units
Each year, Carnegie Mellon fields several teams for participation in the ICPC Regional Programming Contest. During many recent years, one of those teams has earned the right to represent Carnegie Mellon at the ICPC World Finals. This course is a vehicle for those who consistently and rigorously train in preparation for the contests to earn course credit for their effort and achievement. Preparation involves the study of algorithms, the practice of programming and debugging, the development of test sets, and the growth of team, communication, and problem solving skills. Neither the course grade nor the number of units earned are dependent on ranking in any contest. Students are not required to earn course credit to participate in practices or to compete in ACM-ICPC events. Students who have not yet taken 15-295 should register for 15-195; only students who have already taken 15-295 should register for 15-295 again.
Prerequisites: (15-295 Min. grade C or 15-195 Min. grade C) and 15-122 Min. grade C

Course Website: https://contest.cs.cmu.edu/295/

15-300 SEE 07-300 Research and Innovation in Computer Science

Fall: 9 units
This Fall course is the first part of a two-course sequence that is designed to help prepare students to invent the future state-of-the-art in the field of computer science. Course topics will include the following: an overview of important things to know about how research and innovation works in the field of computer science; a survey of the current cutting- edge of computer science research, both here at Carnegie Mellon and elsewhere; critical thinking skills when reading research publications that disagree with each other; strategies for coping with open-ended problems; and technical communication skills for computer scientists. Students will also match up with a faculty mentor for a potential Technology Innovation Project (to be performed in the Spring), put together a detailed plan of attack for that project, and start to get up to speed (including background reading, etc.). This course can be used to satisfy the Technical Communications requirement for the CS major.
Prerequisites: (76-101 Min. grade C and 15-210 Min. grade C and 15-213 Min. grade C) or (15-251 Min. grade C and 15-213 Min. grade C and 76-101 Min. grade C) or (15-251 Min. grade C and 15-210 Min. grade C and 76-101 Min. grade C)

15-311 Logic and Mechanized Reasoning

All Semesters: 9 units
Symbolic logic is fundamental to computer science, providing a foundation for the theory of programming languages, database theory, AI, knowledge representation, automated reasoning, interactive theorem proving, and formal verification. Formal methods based on logic complement statistical methods and machine learning by providing rules of inference and means of representation with precise semantics. These methods are central to hardware and software verification, and have also been used to solve open problems in mathematics. This course will introduce students to logic on three levels: theory, implementation, and application. It will focus specifically on applications to automated reasoning and interactive theorem proving. We will present the underlying mathematical theory, and students will develop the mathematical skills that are needed to design and reason about logical systems in a rigorous way. We will also show students how to represent logical objects in a functional programming language, Lean, and how to implement fundamental logical algorithms. We will show students how to use contemporary automated reasoning tools, including SAT solvers, SMT solvers, and first-order theorem provers to solve challenging problems. Finally, we will show students how to use Lean as an interactive theorem prover.
Prerequisites: (21-128 Min. grade C or 15-151 Min. grade C or 21-127 Min. grade C) and 15-150 Min. grade C

15-312 Foundations of Programming Languages

Fall and Spring: 12 units
This course discusses in depth many of the concepts underlying the design, definition, implementation, and use of modern programming languages. Formal approaches to defining the syntax and semantics are used to describe the fundamental concepts underlying programming languages. A variety of programming paradigms are covered such as imperative, functional, logic, and concurrent programming. In addition to the formal studies, experience with programming in the languages is used to illustrate how different design goals can lead to radically different languages and models of computation.
Prerequisites: 15-150 Min. grade C and (21-228 Min. grade C or 15-251 Min. grade C)

15-313 Foundations of Software Engineering

Fall: 12 units
Students gain exposure to the fundamentals of modern software engineering. This includes both core CS technical knowledge and the means by which this knowledge can be applied in the practical engineering of complex software. Topics related to software artifacts include design models, patterns, coding, static and dynamic analysis, testing and inspection, measurement, and software architecture and frameworks. Topics related to software process include modeling, requirements engineering, process models and evaluation, team development, and supply chain issues including outsourcing and open source. This course has a strong technical focus, and will include both written and programming assignments. Students will get experience with modern software engineering tools.
Prerequisite: 15-214

15-314 Programming Language Semantics

Spring: 12 units
This lecture course introduces the foundational concepts and techniques of programming language semantics. The aim is to demonstrate the utility of a scientific approach, based on mathematics and logic, with applications to program analysis, language design, and compiler correctness. We focus on the most widely applicable frameworks for semantic description: denotational, operational, and axiomatic semantics. We use semantics to analyze program behavior, guide the development of correct programs, prove correctness of a compiler, validate logics for program correctness, and derive general laws of program equivalence. We will discuss imperative and functional languages, sequential and parallel, as time permits.
Prerequisites: 15-150 Min. grade C and 15-251 Min. grade C

15-316 Software Foundations of Security and Privacy

Fall: 9 units
Security and privacy issues in computer systems continue to be a pervasive issue in technology and society. Understanding the security and privacy needs of software, and being able to rigorously demonstrate that those needs are met, is key to eliminating vulnerabilities that cause these issues. Students who take this course will learn the principles needed to make these assurances about software, and some of the key strategies used to make sure that they are correctly implemented in practice. Topics include: policy models and mechanisms for confidentiality, integrity, and availability, language-based techniques for detecting and preventing security threats, mechanisms for enforcing privacy guarantees, and the interaction between software and underlying systems that can give rise to practical security threats. Students will also gain experience applying many of these techniques to write code that is secure by construction.
Prerequisite: 15-213 Min. grade C

Course Website: https://15316-cmu.github.io/2023/index.html (https://15316-cmu.github.io/2023/)

15-317 Constructive Logic

Fall and Spring: 9 units
This multidisciplinary junior-level course is designed to provide a thorough introduction to modern constructive logic, its roots in philosophy, its numerous applications in computer science, and its mathematical properties. Some of the topics to be covered are intuitionistic logic, inductive definitions, functional programming, type theory, realizability, connections between classical and constructive logic, decidable classes.
Prerequisite: 15-150 Min. grade C

Course Website: https://lfcps.org/course/constlog.html

15-319 Cloud Computing

Fall and Spring: 12 units
This course gives students an overview of Cloud Computing, which is the delivery of computing as a service over a network, whereby distributed resources are rented, rather than owned, by an end user as a utility. Students will study its enabling technologies, building blocks, and gain hands-on experience through projects utilizing public cloud infrastructures. Cloud computing services are widely adopted by many organizations across domains. The course will introduce the cloud and cover the topics of data centers, software stack, virtualization, software defined networks and storage, cloud storage, and programming models. We will start by discussing the clouds motivating factors, benefits, challenges, service models, SLAs and security. We will describe several concepts behind data center design and management, which enable the economic and technological benefits of the cloud paradigm. Next, we will study how CPU, memory and I/O resources, network (SDN) and storage (SDS) are virtualized, and the key role of virtualization to enable the cloud. Subsequently, students will study cloud storage concepts like data distribution, durability, consistency and redundancy. We will discuss distributed file systems, NoSQL databases and object storage using HDFS, CephFS, HBASE, MongoDB, Cassandra, DynamoDB, S3, and Swift as case studies. Finally, students will study the MapReduce, Spark and GraphLab programming models. Students will work with Amazon Web Services and Microsoft Azure, to rent and provision compute resources and then program and deploy applications using these resources. Students will develop and evaluate scaling and load balancing solutions, work with cloud storage systems, and develop applications in several programming paradigms. 15619 students must complete an extra team project which entails designing and implementing a cost- and performance-sensitive web-service for querying big data.
Prerequisite: 15-213 Min. grade C

Course Website: https://csd.cs.cmu.edu/course-profiles/15-319-619-Cloud-Computing (https://csd.cs.cmu.edu/course-profiles/15-319-619-Cloud-Computing/)

15-322 Introduction to Computer Music

Spring: 9 units
Computers are used to synthesize sound, process signals, and compose music. Personal computers have replaced studios full of sound recording and processing equipment, completing a revolution that began with recording and electronics. In this course, students will learn the fundamentals of digital audio, basic sound synthesis algorithms, and techniques for digital audio effects and processing. Students will apply their knowledge in programming assignments using a very high-level programming language for sound synthesis and composition. In a final project, students will demonstrate their mastery of tools and techniques through music composition or by the implementation of a significant sound-processing technique.
Prerequisites: 15-122 Min. grade C or 15-112 Min. grade C

Course Website: https://courses.ideate.cmu.edu/15-322 (https://courses.ideate.cmu.edu/15-322/)

15-323 Computer Music Systems and Information Processing

Spring: 9 units
This course presents concepts and techniques for representing and manipulating discrete music information, both in real time and off line. Representations of music as explicitly timed event sequences will be introduced, and students will learn how to build efficient run-time systems for event scheduling, tempo control, and interactive processing. The MIDI protocol is used to capture real-time performance information and to generate sound. The course will also cover non-real-time processing of music data, including Markov models, style recognition, computer accompaniment, query-by-humming, and algorithmic composition. This course is independent of, and complementary to 15-322, Introduction to Computer Music, which focuses on sound synthesis and signal processing.
Prerequisite: 15-122 Min. grade C

15-326 Computational Microeconomics

Intermittent: 9 units
Use of computational techniques to operationalize basic concepts from economics. Expressive marketplaces: combinatorial auctions and exchanges, winner determination problem. Game theory: normal and extensive-form games, equilibrium notions, computing equilibria. Mechanism design: auction theory, automated mechanism design.
Prerequisites: (21-128 Min. grade C or 15-151 Min. grade C or 80-210 or 80-211 Min. grade C or 21-127 Min. grade C) and (36-225 or 36-218 or 36-235 or 21-325)

15-327 Monte Carlo Methods and Applications

Fall: 9 units
The Monte Carlo method uses random sampling to solve computational problems that would otherwise be intractable, and enables computers to model complex systems in nature that are otherwise too difficult to simulate. This course provides a first introduction to Monte Carlo methods from complementary theoretical and applied points of view, and will include implementation of practical algorithms. Topics include random number generation, sampling, Markov chains, Monte Carlo integration, stochastic processes, and applications in computational science. Students need a basic background in probability, multivariable calculus, and some coding experience in any language.
Prerequisites: (21-268 Min. grade C or 21-266 Min. grade C or 21-256 Min. grade C or 21-259 Min. grade C or 21-254 Min. grade C or 21-269 Min. grade C) and (36-235 Min. grade C or 18-465 Min. grade C or 36-218 Min. grade C or 21-325 Min. grade C or 15-259 Min. grade C or 36-219 Min. grade C or 36-225 Min. grade C)

Course Website: http://www.cs.cmu.edu/~kmcrane/random/

15-330 Introduction to Computer Security

Fall and Spring: 12 units
Security is becoming one of the core requirements in the design of critical systems. This course will introduce students to the intro-level fundamental knowledge of computer security and applied cryptography. Students will learn the basic concepts in computer security including software vulnerability analysis and defense, networking and wireless security, and applied cryptography. Students will also learn the fundamental methodology for how to design and analyze security critical systems.
Prerequisite: 15-213 Min. grade C

Course Website: https://www.andrew.cmu.edu/course/18-330/

15-346 Computer Architecture: Design and Simulation

Intermittent: 12 units
This course will help students develop an understanding of basic microarchitectural principles and designs. Starting with creating benchmarks and simulators, students will learn the practice of computer architecture design. The emphasis will be on how processors exploit instruction-level parallelism for performance, as well as the supporting technologies such as caches and branch prediction that are required. Several frontiers of current research will be explored in energy efficiency and security threats.
Prerequisite: 15-213 Min. grade C

15-348 Embedded Systems

Spring: 9 units
This course is offered only at Carnegie Mellon's campus in Qatar. This course covers the broad range of foundational skills that apply across all embedded computer system application areas, from thermostats to self-driving vehicles. The emphasis is at the layer where hardware meets software. Topics include microcontroller hardware, assembly language, embedded C programming, analog I/O, timers, code optimization, interrupts, and concurrency. Real world engineering practices, constraints, and example applications are integrated throughout the course. Weekly hands-on hardware and software experiences with an industry-strength automotive embedded controller are coordinated with the lecture content to reinforce core skills.
Prerequisite: 15-122 Min. grade C

15-349 Introduction to Computer and Network Security

Fall: 9 units
This course is ONLY offered at Carnegie Mellon in Qatar. This course is meant to offer Computer Science undergraduate students in their junior or senior year a broad overview of the field of computer security. Students will learn the basic concepts in computer security including software vulnerability analysis and defense, networking and wireless security, applied cryptography, as well as ethical, legal, social and economic facets of security. Students will also learn the fundamental methodology for how to design and analyze security critical systems.
Prerequisite: 15-122

15-351 Algorithms and Advanced Data Structures

Fall and Spring: 12 units
The objective of this course is to study algorithms for general computational problems, with a focus on the principles used to design those algorithms. Efficient data structures will be discussed to support these algorithmic concepts. Topics include: Run time analysis, divide-and-conquer algorithms, dynamic programming algorithms, network flow algorithms, linear and integer programming, large-scale search algorithms and heuristics, efficient data storage and query, and NP-completeness. Although this course may have a few programming assignments, it is primarily not a programming course. Instead, it will focus on the design and analysis of algorithms for general classes of problems. This course is not open to CS graduate students who should consider taking 15-651 instead. THIS COURSE IS NOT OPEN TO COMPUTER SCIENCE MAJORS OR MINORS.
Prerequisites: 15-122 or 15-121

Course Website: https://www.csd.cs.cmu.edu/course-profiles/15-351-Algorithms-and-Advanced-Data-Structures (https://www.csd.cs.cmu.edu/course-profiles/15-351-Algorithms-and-Advanced-Data-Structures/)

15-354 Computational Discrete Mathematics

Fall: 12 units
This course is about the computational aspects of some of the standard concepts of discrete mathematics (relations, functions, logic, graphs, algebra, automata), with emphasis on efficient algorithms. We begin with a brief introduction to computability and computational complexity. Other topics include: iteration, orbits and fixed points, order and equivalence relations, propositional logic and satisfiability testing, finite fields and shift register sequences, finite state machines, and cellular automata. Computational support for some of the material is available in the form of a Mathematica package.
Prerequisites: 21-228 Min. grade C or 15-251 Min. grade C

Course Website: http://www.cs.cmu.edu/~cdm/

15-355 Modern Computer Algebra

Spring: 9 units
The goal of this course is to investigate the relationship between algebra and computation. The course is designed to expose students to algorithms used for symbolic computation, as well as to the concepts from modern algebra which are applied to the development of these algorithms. This course provides a hands-on introduction to many of the most important ideas used in symbolic mathematical computation, which involves solving system of polynomial equations (via Groebner bases), analytic integration, and solving linear difference equations. Throughout the course the computer algebra system Mathematica will be used for computation.
Prerequisites: 15-251 Min. grade C or 21-228 Min. grade C

Course Website: http://www.andrew.cmu.edu/course/15-355/

15-356 Introduction to Cryptography

Spring: 12 units
This course is aimed as an introduction to modern cryptography. This course will be a mix of applied and theoretical cryptography. We will cover popular primitives such as: pseudorandom functions, encryption, signatures, zero-knowledge proofs, multi-party computation, and Blockchains. In addition, we will cover the necessary number-theoretic background. We will cover formal definitions of security, as well as constructions based on well established assumptions like factoring. Please see the course webpage for a detailed list of topics.
Prerequisites: 15-251 Min. grade C or 21-228

Course Website: http://www.cs.cmu.edu/~goyal/15356/

15-359 Probability & Computing: Randomized Algs and Markov Chains

Intermittent: 12 units
Probability theory has become indispensable in computer science. In areas such as artificial intelligence and computer science theory, probabilistic methods and ideas based on randomization are central. In other areas such as networks and systems, probability is becoming an increasingly useful framework for handling uncertainty and modeling the patterns of data that occur in complex systems. This course is a follow-up course to 15-259, Probability and Computing. It will cover Chapters 18-27 of the same textbook, "Introduction to Probability for Computing", by Prof. Harchol-Balter. Topics include concentration inequalities, various randomized algorithms including number theoretic routines, Markov chains and their many applications, and queuing theory. The course will assume familiarity with multivariate calculus and linear algebra.
Prerequisites: 21-325 Min. grade C or 15-259 Min. grade C

15-362 Computer Graphics

Fall and Spring: 12 units
This course provides a comprehensive introduction to computer graphics modeling, animation, and rendering. Topics covered include basic image processing, geometric transformations, geometric modeling of curves and surfaces, animation, 3-D viewing, visibility algorithms, shading, and ray tracing.
Prerequisites: (21-240 Min. grade C and 15-122 Min. grade C and 21-122 Min. grade C) or (15-122 Min. grade C and 21-122 Min. grade C and 21-241 Min. grade C) or (15-122 Min. grade C and 21-254 Min. grade C) or (15-122 Min. grade C and 18-202 Min. grade C)

15-365 Experimental Animation

Intermittent: 12 units
This class will explore animation from the student's perspective with a sense of investigation toward both form and content. Topics in the class will include non-linear narrative, visual music, puppet and non-traditional materials, manipulation of motion and performance capture data, immersive environments.
Prerequisite: 15-213 Min. grade C

15-367 Algorithmic Textiles Design

Intermittent: 12 units
Textile artifacts are and #8212; quite literally and #8212; all around us; from clothing to carpets to car seats. These items are often produced by sophisticated, computer-controlled fabrication machinery. In this course we will discuss everywhere code touches textiles fabrication, including design tools, simulators, and machine control languages. Students will work on a series of multi-week, open-ended projects, where they use code to create patterns for modern sewing/embroidery, weaving, and knitting machines; and then fabricate these patterns in the textiles lab. Students in the 800-level version of the course will additionally be required to create a final project that develops a new algorithm, device, or technique in textiles fabrication.

Course Website: http://graphics.cs.cmu.edu/courses/15-869K-s21/

15-369 Special Topics: Perceptual Computing

Intermittent: 9 units
This course is ONLY offered at Carnegie Mellon in Qatar. What can today's computers see, hear, and feel? This project-based course is designed to provide students exposure to the state-of-the-art in machine perception and the algorithms behind them. Student groups will design a perceptual computing project around Intel's Creative Camera or Microsoft's Kinect. Students will learn to use tools in face detection and recognition, hand and finger tracking, and speech recognition, along with algorithms to make decisions based on these input modalities.
Prerequisites: 15-122 and 21-241

15-382 Collective Intelligence

Spring: 9 units
This course is about the study of distributed control and intelligence systems involving a large number of autonomous components that interact with each other, dynamically adapting to their changing environment as a result of mutual interactions. Examples of such components include cars in city traffic, pedestrians moving in crowds, firms competing in a market, ants foraging for food, or mobile robots in a swarm or multi-robot system. Under certain conditions, such systems can produce useful system-level behaviors, display self-organized spatial-temporal patterns, effectively perform computations, information dissemination, and decision-making. Loosely speaking, when this happens we can say that the system is displaying a form of "collective intelligence". Collective intelligence will expose students to relevant mathematical and computational models from following fields and domains: Cellular automata and Random boolean networks, Social choice, Game theory, Distributed consensus, Task allocation, Swarm intelligence, Social networks, Pattern formation, and Self-organizing maps. The course will also help bridge the gap between theory and practice via assignments where students will implement system models and explore their properties in application domains of practical interest.
Prerequisite: 15-122 Min. grade C

15-383 Introduction to Text Processing

Fall: 6 units
Text processing is a mini-course about text basic techniques of processing human language in text format. The course has theoretical and hands-on components. In the theoretical component, the course will discuss challenges in processing human languages, and review the basics of statistics and probability theory and their application to language problems. In the hands-on part, students will learn about Python programming and use it to process large volumes of text using various techniques. The processing will range from simple steps such as tokenization and part-of-speech tagging to full-fledged applications such as statistical machine translation, search and document/topic classification. The course is suited for junior and senior students in CS and IS.
Prerequisites: 15-121 Min. grade C or 15-122 Min. grade C

15-385 Introduction to Computer Vision

Spring: 6 units
An introduction to the science and engineering of computer vision, i.e. the analysis of the patterns in visual images with the view to understanding the objects and processes in the world that generate them. Major topics include image formation and sensing, fourier analysis, edge and contour detection, inference of depth, shape and motion, classification, recognition, tracking, and active vision. The emphasis is on the learning of fundamental mathematical concepts and techniques and applying them to solve real vision problems. The discussion will also include comparison with human and animal vision from psychological and biological perspectives. Students will learn to think mathematically and develop skills in translating ideas and mathematical thoughts into programs to solve real vision problems.
Prerequisites: 15-122 Min. grade C and 21-241

15-386 Neural Computation

Spring: 9 units
Computational neuroscience is an interdisciplinary science that seeks to understand how the brain computes to achieve natural intelligence. It seeks to understand the computational principles and mechanisms of intelligent behaviors and mental abilities and #8212; such as perception, language, motor control, and learning and #8212; by building artificial systems and computational models with the same capabilities. This course explores how neurons encode and process information, adapt and learn, communicate, cooperate, compete and compute at the individual level as well as at the levels of networks and systems. It will introduce basic concepts in computational modeling, information theory, signal processing, system analysis, statistical and probabilistic inference. Concrete examples will be drawn from the visual system and the motor systems, and studied from computational, psychological and biological perspectives. Students will learn to perform computational experiments using Matlab and quantitative studies of neurons and neuronal networks.
Prerequisites: (15-122 Min. grade C or 15-112 Min. grade C) and 21-122

15-387 Computational Perception

Fall and Spring: 9 units
In this course, we will first cover the biological and psychological foundational knowledge of biological perceptual systems, and then apply computational thinking to investigate the principles and mechanisms underlying natural perception. The course will focus on vision this year, but will also touch upon other sensory modalities. You will learn how to reason scientifically and computationally about problems and issues in perception, how to extract the essential computational properties of those abstract ideas, and finally how to convert these into explicit mathematical models and computational algorithms. Topics include perceptual representation and inference, perceptual organization, perceptual constancy, object recognition, learning and scene analysis. Prerequisites: First year college calculus, some basic knowledge of linear algebra and probability and some programming experience are desirable.
Prerequisites: 21-122 and 21-241 and 15-112 Min. grade C

15-388 Practical Data Science

Intermittent: 9 units
Data science is the study and practice of how we can extract insight and knowledge from large amounts of data. This course provides a practical introduction to the "full stack" of data science analysis, including data collection and processing, data visualization and presentation, statistical model building using machine learning, and big data techniques for scaling these methods. Topics covered include: collecting and processing data using relational methods, time series approaches, graph and network models, free text analysis, and spatial geographic methods; analyzing the data using a variety of statistical and machine learning methods include linear and non-linear regression and classification, unsupervised learning and anomaly detection, plus advanced machine learning methods like kernel approaches, boosting, or deep learning; visualizing and presenting data, particularly focusing the case of high-dimensional data; and applying these methods to big data settings, where multiple machines and distributed computation are needed to fully leverage the data.Students will complete weekly programming homework that emphasize practical understanding of the methods described in the course. In addition, students will develop a tutorial on an advanced topic, and will complete a group project that applies these data science techniques to a practical application chosen by the team; these two longer assignments will be done in lieu of a midterm or final.
Prerequisites: 15-122 Min. grade C or 15-112 Min. grade C

Course Website: http://www.datasciencecourse.org

15-390 Entrepreneurship for Computer Science

Fall: 9 units
This course is designed to develop skills related to entrepreneurship and innovation for non-business undergraduate and graduate students in the School of Computer Science. The course assumes no background courses in business and is appropriate for those who are interested in bringing innovations to market either through new companies or existing companies. The course provides an overview of entrepreneurship and innovation, develops an entrepreneurial frame of mind, and provides a framework for learning the rudiments of how to generate ideas. Students come up with or are presented with potential ideas and learn how to develop these ideas into opportunities, and to explore their potential for becoming viable businesses. They learn how to do market research, to develop go-to-market strategies, value propositions and to differentiate their products or services from potential competitors. The focus is on understanding and developing strategies for approaching the key elements of the entrepreneurial process...opportunity, resources and team. The course consists of a balance of lectures, case studies and encounters with entrepreneurs, investors and business professionals. The students are exposed to financial and intellectual property issues, and encounter a real world perspective on entrepreneurship, innovation and leadership. The output of the course is a mini-business plan or venture opportunity screening document that can be developed into a business plan in a subsequent course entitled New Venture Creation or through independent study.
Prerequisite: 15-112 Min. grade C

15-392 Special Topic: Secure Programming

Spring: 9 units
This course provides a detailed explanation of common programming errors in C and C++ and describes how these errors can lead to software systems that are vulnerable to exploitation. The course concentrates on security issues intrinsic to the C and C++ programming languages and associated libraries. It does not emphasize security issues involving interactions with external systems such as databases and web servers, as these are rich topics on their own. Topics to be covered include the secure and insecure use of integers, arrays, strings, dynamic memory, formatted input/output functions, and file I/O.
Prerequisite: 15-213 Min. grade C

Course Website: https://www.securecoding.cert.org/confluence/display/sci/15392+Secure+Programming (https://www.securecoding.cert.org/confluence/display/sci/15392+Secure+Programming/)

15-394 Intermediate Rapid Prototyping

Fall and Spring: 5 units
This course covers additional topics in rapid prototyping beyond the content of 15-294. Example topics include mechanism design, procedural shape generation using Grasshopper, 3D scanning and mesh manipulation, and advanced SolidWorks concepts. The only prerequisite is basic familiarity with SolidWorks, which can be obtained via 15-294, from other CMU courses, or from online tutorials.

Course Website: https://www.cs.cmu.edu/afs/cs.cmu.edu/academic/class/15394-f21/

15-400 SEE 07-400 Research Practicum in Computer Science

Spring: 12 units
This Spring course is the second part of a two-course sequence that is designed to help prepare students to invent the future state-of-the-art in the field of computer science. Building directly upon 15-300 (the prerequisite for this course), students will conduct a semester-long independent research project, under the guidance of both the course staff and a faculty project mentor. The course does not meet for lecture or recitations. Instead, the students will spend their time working on their research projects, and will also meet with course staff on a bi-weekly basis to discuss their progress. Students will prepare a written report and a poster presentation at the end of the semester to describe what they have accomplished.
Prerequisite: 15-300 Min. grade C

15-405 Engineering Distributed Systems

Spring: 9 units
This is a course for students with strong design and implementation skills who are likely to pursue careers as software architects and lead engineers. It may be taken by well-prepared undergraduates with excellent design and implementation skills in low-level systems programing. The course assumes a high level of proficiency in all aspects of operating system design and implementation. This course will help students prepare for leadership roles in creating and evolving the complex, large-scale computer systems that society will increasingly depend on in the future. The course will teach the organizing principles of such systems, identifying a core set of versatile techniques that are applicable across many system layers. Students will acquire the knowledge base, intellectual tools, hands-on skills and modes of thought needed to build well-engineered computer systems that withstand the test of time, growth in scale, and stresses of live use. Topics covered include: caching, prefetching, damage containment, scale reduction, hints, replication, hash-based techniques, and fragmentation reduction. A substantial project component is an integral part of the course. A high level of proficiency in systems programming is expected. If you do not have the 15-410 prerequisite you will need to get approval from the faculty.
Prerequisite: 15-410 Min. grade B

15-410 Operating System Design and Implementation

Fall and Spring: 15 units
Operating System Design and Implementation is a rigorous hands-on introduction to the principles and practice of operating systems. The core experience is writing a small Unix-inspired OS kernel, in C with some x86 assembly language, which runs on a PC hardware simulator (and on actual PC hardware if you wish). Work is done in two-person teams, and "team programming" skills (source control, modularity, documentation) are emphasized. The size and scope of the programming assignments typically result in students significantly developing their design, implementation, and debugging abilities. Core concepts include the process model, virtual memory, threads, synchronization, and deadlock; the course also surveys higher-level OS topics including file systems, interprocess communication, networking, and security. Students, especially graduate students, who have not satisfied the prerequisite at Carnegie Mellon are strongly cautioned - to enter the class you must be able to write a storage allocator in C, use a debugger, understand 2's-complement arithmetic, and translate between C and x86 assembly language. The instructor may require you to complete a skills assessment exercise before the first week of the semester in order to remain registered in the class. Auditing: this course is usually full, and we generally receive many more requests to audit than we can accept. If you wish to audit, please have your advisor contact us before the semester begins to discuss your educational goals.
Prerequisites: 15-411 Min. grade B or 15-418 Min. grade B or 15-440 Min. grade B or 15-441 Min. grade B or 15-445 Min. grade B or 18-447 Min. grade B

Course Website: https://www.csd.cs.cmu.edu/course-profiles/15-410_605-Operating-System-Design-and-Implementation (https://www.csd.cs.cmu.edu/course-profiles/15-410_605-Operating-System-Design-and-Implementation/)

15-411 Compiler Design

Spring: 15 units
This course covers the design and implementation of compiler and run-time systems for high-level languages, and examines the interaction between language design, compiler design, and run-time organization. Topics covered include syntactic and lexical analysis, handling of user-defined types and type-checking, context analysis, code generation and optimization, and memory management and run-time organization.
Prerequisite: 15-213 Min. grade C

Course Website: https://www.cs.cmu.edu/~janh/courses/411/23/index.html (https://www.cs.cmu.edu/~janh/courses/411/23/)

15-412 Operating System Practicum

Fall
The goal of this class is for students to acquire hands-on experience with operating-system code as it is developed and deployed in the real world. Groups of two to four students will select, build, install, and become familiar with an open-source operating system project; propose a significant extension or upgrade to that project; and develop a production-quality implementation meeting the coding standards of that project. Unless infeasible, the results will be submitted to the project for inclusion in the code base. Variations on this theme are possible at the discretion of the instructor. For example, it may be possible to work within the context of a non-operating-system software infrastructure project (window system, web server, or embedded network device kernel) or to extend a 15-410 student kernel. In some situations students may work alone. Group membership and unit count (9 units versus 12) will be decided by the third week of the semester. Contributing to a real-world project will involve engaging in some mixture of messy, potentially open-ended activities such as: learning a revision control system, writing a short design document, creating and updating a simple project plan, participating in an informal code review, synthesizing scattered information about hardware and software, classifying and/or reading large amounts of code written by various people over a long period of time, etc.
Prerequisite: 15-410

15-413 SEE 17-413 Software Engineering Practicum

Spring: 12 units
CHANGED TO 17-413 STARTING SPRING 2018. This course is a project-based course in which students conduct a semester-long project for a real client in small teams. The project defines real world needs for the client in their company. This is not a lecture-based course; after the first few weeks the course consists primarily of weekly team meetings with the course instructors, with teams making regular presentations on their software development process. Teams will give presentations and deliver documents on topics such as: risk management project planning requirements architecture detailed design quality assurance final product presentations reflections on the experience Evaluation will be based on the in-class presentations, process and project documentation, how well the teams follow software engineering (SE) practices, and the client's satisfaction with the product. Individual grades will be influenced by peer reviews, individual reflection documents, mentor impressions, and presentation performance. Students will leave the course with a firsthand understanding of the software engineering realities that drive SE practices, will have concrete experience with these practices, and will have engaged in active reflection on this experience. They will have teamwork, process, and product skills to support immediate competency in a software engineering organization, along with a deeper understanding that prepares them to evaluate the new processes and techniques they will encounter in the workplace.

15-414 Bug Catching: Automated Program Verification

Spring: 9 units
Many CS and ECE students will be developing software and hardware that must be ultra reliable at some point in their careers. Logical errors in such designs can be costly, even life threatening. There have already been a number of well publicized errors like the Intel Pentium floating point error and the Arian 5 crash. In this course we will study tools for finding and preventing logical errors. Three types of tools will be studied: automated theorem proving, state exploration techniques like model checking and tools based on static program analysis. Although students will learn the theoretical basis for such tools, the emphasis will be on actually using them on real examples. This course can be used to satisfy the Logic and amp; Languages requirement for the Computer Science major.
Prerequisites: 15-122 Min. grade C and 15-251 Min. grade C

Course Website: http://www.cs.cmu.edu/~15414/

15-415 Database Applications

Fall: 12 units
This course covers the fundamental topics for Database Management Systems: Database System Architectural Principles (ACID properties; data abstraction; external, conceptual, and internal schemata; data independence; data definition and data manipulation languages), Data models (entity-relationship and relational data models; data structures, integrity constraints, and operations for each data model; relational query languages: SQL, algebra, calculus), Theory of database design (functional dependencies; normal forms; dependency preservation; information loss), Query Optimization (equivalence of expressions, algebraic manipulation; optimization of selections and joins), Storage Strategies (indices, B-trees, hashing), Query Processing (execution of sort, join, and aggregation operators), and Transaction Processing (recovery and concurrency control).
Prerequisites: 15-210 Min. grade C and 15-213 Min. grade C

Course Website: http://15415.courses.cs.cmu.edu/

15-417 HOT Compilation

Intermittent: 12 units
The course covers the implementation of compilers for higher-order, typed languages such as ML and Haskell, and gives an introduction to type-preserving compilation. Topics covered include type inference, elaboration, CPS conversion, closure conversion, garbage collection, phase splitting, and typed assembly language.
Prerequisites: 15-312 or 15-317

Course Website: https://www.cs.cmu.edu/~crary/hotc/

15-418 Parallel Computer Architecture and Programming

Fall and Spring: 12 units
The fundamental principles and engineering tradeoffs involved in designing modern parallel computers, as well as the programming techniques to effectively utilize these machines. Topics include naming shared data, synchronizing threads, and the latency and bandwidth associated with communication. Case studies on shared-memory, message-passing, data-parallel and dataflow machines will be used to illustrate these techniques and tradeoffs. Programming assignments will be performed on one or more commercial multiprocessors, and there will be a significant course project.
Prerequisite: 15-213 Min. grade C

Course Website: http://15418.courses.cs.cmu.edu

15-421 Information Security and Privacy

Fall: 12 units
As layers upon layers of technology mediate our activities, issues of information security and privacy are becoming increasingly pervasive and complex. This course takes a multi-disciplinary perspective of information security and privacy, looking at technologies as well as business, legal, policy and usability issues. The objective is to prepare students to identify and address critical security and privacy issues involved in the design, development and deployment of robust computer and information systems. Examples used to introduce concepts covered in the class range from enterprise systems to mobile computing, the Internet of Things, social networking and digital currencies. Topics Covered: Information Security and Privacy: the big picture; A gentle introduction to cryptography; Certificates, PKI, Decentralized Trust Management; Authentication; Internet Security protocols; Risk management; Trusted Computing; Systems security; Web attacks; Cybercrime; Understanding the cyber security legal landscape; Information Privacy: Fundamental concepts and amp; legal landscape; Privacy and Big Data; Privacy Enhancing Technologies; Privacy Engineering; Usable Security and Privacy; Electronic payments and digital currencies; Emerging Security and Privacy challenges (e.g. Cloud Security and Privacy, Mobile and IoT Security and Privacy, Social Networking Security and Privacy)

Prerequisites: 76-101 and 15-112

Course Website: http://www.normsadeh.com/isp-content (http://www.normsadeh.com/isp-content/)

15-423 Special Topic: Digital Signal Processing for Computer Science

Spring: 12 units
Digital signals comprise a large fraction of the data analyzed by computer scientists. Sound, e.g. speech and music, images, radar and many other signal types that were conventionally considered to be the domain of the Electrical engineer are now also in the domain of computer scientists, who must analyze them, make inferences, and develop machine learning techinques to analyze, classify and reconstruct such data. In this course we will cover the basics of Digital Signal Processing. We will concentrate on the basic mathematical formulations, rather than in-depth implementation details. We will cover the breadth of topics, beginning with the basics of signals and their representations, the theory of sampling, important transform representations, key processing techniques, and spectral estimation.
Prerequisites: (15-122 Min. grade C or 15-112 Min. grade C) and (15-359 or 36-625 or 21-325 or 36-217 or 36-225)

15-424 Logical Foundations of Cyber-Physical Systems

Intermittent: 12 units
Cyber-physical systems (CPSs) combine cyber capabilities (computation and/or communication) with physical capabilities (motion or other physical processes). Cars, aircraft, and robots are prime examples, because they move physically in space in a way that is determined by discrete computerized control algorithms. Designing these algorithms to control CPSs is challenging due to their tight coupling with physical behavior. At the same time, it is vital that these algorithms be correct, since we rely on CPSs for safety-critical tasks like keeping aircraft from colliding. This course pursues the fundamental question: "How can we provide people with cyber-physical systems they can bet their lives on?"
Prerequisites: 15-122 Min. grade C and 21-120 Min. grade C

Course Website: http://lfcps.org/course/lfcps.html

15-435 Foundations of Blockchains

Fall: 12 units
In this course, students will learn the mathematical foundations of blockchains, including how to construct distributed consensus protocols and prove them secure, cryptography for blockchains, and mechanism design for blockchains. This course will take a mathematically rigorous approach. Students are expected to have mathematical maturity and be able to write formal mathematical proofs. Students may also be expected to implement some consensus or cryptographic algorithms. This course is cross-listed with 15-635. Undergraduates should enroll in 15-435. Graduates students should enroll in 15-635.
Prerequisites: 15-251 Min. grade C or 15-210 Min. grade C or 15-330

15-437 Web Application Development

Fall and Spring: 12 units
This course will introduce concepts in programming web application servers. We will study the fundamental architectural elements of programming web sites that produce content dynamically. The primary technology introduced will be the Django framework for Python, but we will cover related topics as necessary so that students can build significant applications. Such topics include: HTTP, HTML, CSS, Javascript, XML, Design Patterns, Relational and Non-relational Databases, Object-Relation Mapping tools, Security, Web Services, Cloud Deployment, Internationalization, and Scalability and Performance Issues. Students must have programming and software design experience equivalent to about a typical Junior CS major and #8212;-a sequence of three college CS courses or more. Python-specific experience is not necessary. Students must provide their own computer hardware for this course. Please see the Related URL above for more information.
Prerequisite: 15-214

15-439 Special Topics: Blockchains and Cryptocurrencies

Intermittent: 12 units
Introduction to Blockchains and Cryptocurrencies. We focus on the cryptographic and mathematical foundations of Blockchains. The course will start from the basics and will cover the latest research in this area towards the end.

15-440 Distributed Systems

Fall and Spring: 12 units
The goals of this course are twofold: First, for students to gain an understanding of the principles and techniques behind the design of distributed systems, such as locking, concurrency, scheduling, and communication across the network. Second, for students to gain practical experience designing, implementing, and debugging real distributed systems. The major themes this course will teach include scarcity, scheduling, concurrency and concurrent programming, naming, abstraction and modularity, imperfect communication and other types of failure, protection from accidental and malicious harm, optimism, and the use of instrumentation and monitoring and debugging tools in problem solving. As the creation and management of software systems is a fundamental goal of any undergraduate systems course, students will design, implement, and debug large programming projects. As a consequence, competency in both the C and Java programming languages is required.
Prerequisite: 15-213 Min. grade C

Course Website: https://www.synergylabs.org/courses/15-440/

15-441 Networking and the Internet

Fall: 12 units
The emphasis in this course will be on the basic performance and engineering trade-offs in the design and implementation of computer networks. To make the issues more concrete, the class includes several multi-week projects requiring significant design and implementation. The goal is for students to learn not only what computer networks are and how they work today, but also why they are designed the way they are and how they are likely to evolve in the future. We will draw examples primarily from the Internet. Topics to be covered include: network architecture, routing, congestion/flow/error control, naming and addressing, peer-to-peer and the web, internetworking, and network security.
Prerequisite: 15-213 Min. grade C

15-442 Machine Learning Systems

Spring: 12 units
The goal of this course is to provide students an understanding and overview of elements in modern machine learning systems. Throughout the course, the students will learn about the design rationale behind the state-of-the-art machine learning frameworks and advanced system techniques to scale, reduce memory, and offload heterogeneous compute resources. We will also run case studies of large-scale training and serving systems used in practice today. This course offers the necessary background for students who would like to pursue research in the area of machine learning systems or continue to work in machine learning engineering.
Prerequisites: (21-128 Min. grade C or 15-151 Min. grade C or 21-127 Min. grade C) and 21-241 Min. grade C and (11-485 or 10-701 or 10-315 or 10-301 or 15-281) and (15-513 Min. grade C or 15-213 Min. grade C or 18-600 Min. grade C or 18-213 Min. grade C)

15-445 Database Systems

Fall: 12 units
This course is on the design and implementation of database management systems. Topics include data models (relational, document, key/value), storage models (n-ary, decomposition), query languages (SQL, stored procedures), storage architectures (heaps, log-structured), indexing (order preserving trees, hash tables), transaction processing (ACID, concurrency control), recovery (logging, checkpoints), query processing (joins, sorting, aggregation, optimization), and parallel architectures (multi-core, distributed). Case studies on open-source and commercial database systems will be used to illustrate these techniques and trade-offs. The course is appropriate for students with strong systems programming skills.
Prerequisite: 15-213 Min. grade C

Course Website: http://15445.courses.cs.cmu.edu

15-449 Engineering Distributed Systems

Spring: 9 units
This is a course for students with strong design and implementation skills who are likely to pursue careers as software architects and lead engineers. It may be taken by well-prepared undergraduates with excellent design and implementation skills in low-level systems programing. The course assumes a high level of proficiency in all aspects of operating system design and implementation. This course will help students prepare for leadership roles in creating and evolving the complex, large-scale computer systems that society will increasingly depend on in the future. The course will teach the organizing principles of such systems, identifying a core set of versatile techniques that are applicable across many system layers. Students will acquire the knowledge base, intellectual tools, hands-on skills and modes of thought needed to build well-engineered computer systems that withstand the test of time, growth in scale, and stresses of live use. Topics covered include: caching, prefetching, damage containment, scale reduction, hints, replication, hash-based techniques, and fragmentation reduction. A substantial project component is an integral part of the course. A high level of proficiency in systems programming is expected. If you do not have the 15-410 prerequisite you will need to get approval from the faculty.
Prerequisite: 15-410 Min. grade B

15-451 Algorithm Design and Analysis

Fall and Spring: 12 units
This course is about the design and analysis of algorithms. We study specific algorithms for a variety of problems, as well as general design and analysis techniques. Specific topics include searching, sorting, algorithms for graph problems, efficient data structures, lower bounds and NP-completeness. A variety of other topics may be covered at the discretion of the instructor. These include parallel algorithms, randomized algorithms, geometric algorithms, low level techniques for efficient programming, cryptography, and cryptographic protocols.
Prerequisites: 15-210 Min. grade C and 21-241 Min. grade C and (21-228 Min. grade C or 15-251 Min. grade C)

Course Website: https://www.csd.cs.cmu.edu/course-profiles/15-451-Algorithm-Design-and-Analysis (https://www.csd.cs.cmu.edu/course-profiles/15-451-Algorithm-Design-and-Analysis/)

15-453 Formal Languages, Automata, and Computability

Intermittent: 9 units
An introduction to the fundamental ideas and models underlying computing: finite automata, regular sets, pushdown automata, context-free grammars, Turing machines, undecidability, and complexity theory.
Prerequisites: 21-228 Min. grade C or 15-251 Min. grade C

15-455 Undergraduate Complexity Theory

Fall and Spring: 9 units
Complexity theory is the study of how much of a resource (such as time, space, parallelism, or randomness) is required to perform some of the computations that interest us the most. In a standard algorithms course, one concentrates on giving resource efficient methods to solve interesting problems. In this course, we concentrate on techniques that prove or suggest that there are no efficient methods to solve many important problems. We will develop the theory of various complexity classes, such as P, NP, co-NP, PH, #P, PSPACE, NC, AC, L, NL, UP, RP, BPP, IP, and PCP. We will study techniques to classify problems according to our available taxonomy. By developing a subtle pattern of reductions between classes we will suggest an (as yet unproven!) picture of how by using limited amounts of various resources, we limit our computational power.
Prerequisite: 15-251 Min. grade C

15-456 Computational Geometry

Intermittent: 9 units
How do you sort points in space? What does it even mean? This course takes the ideas of a traditional algorithms course, sorting, searching, selecting, graphs, and optimization, and extends them to problems on geometric inputs. We will cover many classical geometric constructions and novel algorithmic methods. Some of the topics to be covered are convex hulls, Delaunay triangulations, graph drawing, point location, geometric medians, polytopes, configuration spaces, linear programming, and others. This course is a natural extension to 15-451, for those who want to learn about algorithmic problems in higher dimensions.
Prerequisite: 15-451 Min. grade C

15-457 Special Topics in Theory: Advanced Algorithms

Intermittent: 12 units
Selected advanced topics in algorithms and computational theory. Topics vary from semester to semester.
Prerequisite: 15-451 Min. grade B

15-458 Discrete Differential Geometry

Spring: 12 units
This course focuses on three-dimensional geometry processing, while simultaneously providing a first course in traditional differential geometry. Our main goal is to show how fundamental geometric concepts (like curvature) can be understood from complementary computational and mathematical points of view. This dual perspective enriches understanding on both sides, and leads to the development of practical algorithms for working with real-world geometric data. Along the way we will revisit important ideas from calculus and linear algebra, putting a strong emphasis on intuitive, visual understanding that complements the more traditional formal, algebraic treatment. The course provides essential mathematical background as well as a large array of real-world examples and applications. It also provides a short survey of recent developments in digital geometry processing and discrete differential geometry. Topics include: curves and surfaces, curvature, connections and parallel transport, exterior algebra, exterior calculus, Stokes' theorem, simplicial homology, de Rham cohomology, Helmholtz-Hodge decomposition, conformal mapping, finite element methods, and numerical linear algebra. Applications include: approximation of curvature, curve and surface smoothing, surface parameterization, vector field design, and computation of geodesic distance.

Prerequisites: (02-201 Min. grade C or 15-110 Min. grade C or 15-122 Min. grade C or 15-112 Min. grade C) and (21-254 Min. grade C or 21-242 Min. grade C or 21-240 Min. grade C or 21-241 Min. grade C or 21-341 Min. grade C) and (21-259 Min. grade C or 21-254 Min. grade C or 21-269 Min. grade C or 21-256 Min. grade C or 21-268 Min. grade C)

Course Website: http://geometry.cs.cmu.edu/ddg (http://geometry.cs.cmu.edu/ddg/)

15-459 Undergraduate Quantum Computation

Intermittent: 9 units
This undergraduate course will be an introduction to quantum computation and quantum information theory, from the perspective of theoretical computer science. Topics include: Qubit operations, multi-qubit systems, p=artial measurements, entanglement, quantum teleportation and quantum money, quantum circuit model, Deutsch-Jozsa and Simon's algorithm, number theory and Shor's Algorithm, Grover's Algorithm, quantum complexity theory, limitations and current practical developments.
Prerequisites: (15-210 Min. grade C or 15-251 Min. grade C) and (36-225 or 36-218 or 33-341 or 21-325 or 15-259) and (33-341 or 21-241 Min. grade C or 21-242)

15-462 Computer Graphics

Fall and Spring: 12 units
This course provides a comprehensive introduction to computer graphics modeling, animation, and rendering. Topics covered include basic image processing, geometric transformations, geometric modeling of curves and surfaces, animation, 3-D viewing, visibility algorithms, shading, and ray tracing.
Prerequisites: (21-240 Min. grade C and 21-259 Min. grade C and 15-213 Min. grade C) or (21-241 Min. grade C and 15-213 Min. grade C and 21-259 Min. grade C) or (18-213 Min. grade C and 18-202 Min. grade C)

15-463 Computational Photography

Fall: 12 units
Computational photography is the convergence of computer graphics, computer vision and imaging. Its role is to overcome the limitations of the traditional camera, by combining imaging and computation to enable new and enhanced ways of capturing, representing, and interacting with the physical world. This advanced undergraduate course provides a comprehensive overview of the state of the art in computational photography. At the start of the course, we will study modern image processing pipelines, including those encountered on mobile phone and DSLR cameras, and advanced image and video editing algorithms. Then we will proceed to learn about the physical and computational aspects of tasks such as 3D scanning, coded photography, lightfield imaging, time-of-flight imaging, VR/AR displays, and computational light transport. Near the end of the course, we will discuss active research topics, such as creating cameras that capture video at the speed of light, cameras that look around walls, or cameras that can see through tissue. The course has a strong hands-on component, in the form of seven homework assignments and a final project. In the homework assignments, students will have the opportunity to implement many of the techniques covered in the class, by both acquiring their own images of indoor and outdoor scenes and developing the computational tools needed to extract information from them. For their final projects, students will have the choice to use modern sensors provided by the instructors (lightfield cameras, time-of-flight cameras, depth sensors, structured light systems, etc.). This course requires familarity with linear algebra, calculus, programming, and doing computations with images. The course does not require prior experience with photography or imaging.
Prerequisites: 16-720 Min. grade C or 15-462 Min. grade C or 16-385 Min. grade C or 18-793 Min. grade C

Course Website: http://graphics.cs.cmu.edu/courses/15-463/

15-464 Technical Animation

Spring: 12 units
This course introduces techniques for computer animation such as keyframing, procedural methods, motion capture, and simulation. The course also includes a brief overview of story-boarding, scene composition, lighting and sound track generation. The second half of the course will explore current research topics in computer animation such as dynamic simulation of flexible and rigid objects,automatically generated control systems, and evolution of behaviors. The course should be appropriate for graduate students in all areas and for advanced undergraduates.
Prerequisite: 15-462 Min. grade C

15-465 Animation Art and Technology

Spring: 12 units
Animation, Art, and Technology is an interdisciplinary, Art and Computer Science, cross-listed course. Faculty and teaching assistants from computer science and art teach the class as a team. It is a project-based course in which interdisciplinary teams of students can produce animations across platforms from single channel to augmented reality. Most of the animations have a substantive technical component and the students are challenged to consider innovation with content to be equal with the technical. The class includes basic tutorials for work in Maya and Unity leading toward more advanced applications and extensions of the software such as motion capture and algorithms for animating cloth, hair, particles, and immersive technologies.
Prerequisites: 15-213 Min. grade C or 18-213 Min. grade C

15-466 Computer Game Programming

Fall: 12 units
The goal of this course is to acquaint students with the code required to turn ideas into games. This includes both runtime systems and #8212; e.g., AI, sound, physics, rendering, and networking and #8212; and the asset pipelines and creative tools that make it possible to author content that uses these systems. In the first part of the course, students will implement small games that focus on specific runtime systems, along with appropriate asset editors or exporters. In the second part, students will work in groups to build a larger, polished, open-ended game project. Students who have completed the course will have the skills required to extend and #8212; or build from scratch and #8212; a modern computer game. Students wishing to take this class should be familiar with the C++ language and have a basic understanding of the OpenGL API. If you meet these requirements but have not taken Computer Graphics (the formal prerequisite), please contact the instructor.
Prerequisite: 15-462

Course Website: http://graphics.cs.cmu.edu/courses/15-466/

15-468 Physics-Based Rendering

Spring: 12 units
This course is an introduction to physics-based rendering at the advanced undergraduate and introductory graduate level. During the course, we will cover fundamentals of light transport, including topics such as the rendering and radiative transfer equation, light transport operators, path integral formulations, and approximations such as diffusion and single scattering. Additionally, we will discuss state-of-the-art models for illumination, surface and volumetric scattering, and sensors. Finally, we will use these theoretical foundations to develop Monte Carlo algorithms and sampling techniques for efficiently simulating physically-accurate images. Towards the end of the course, we will look at advanced topics such as rendering wave optics, neural rendering, and differentiable rendering. The course has a strong programming component, during which students will develop their own working implementation of a physics-based renderer, including support for a variety of rendering algorithms, materials, illumination sources, and sensors. The project also includes a final project, during which students will select and implement some advanced rendering technique, and use their implementation to produce an image that is both technically and artistically compelling. The course will conclude with a rendering competition, where students submit their rendered images to win prizes. Cross-listing: This is both an advanced undergraduate and introductory graduate course, and it is cross-listed as 15-468 (for undergraduate students), 15-668 (for Master's students), and 15-868 (for PhD students). Please make sure to register for the section of the class that matches your current enrollment status.
Prerequisites: 16-385 or 16-720 or 15-462

Course Website: http://graphics.cs.cmu.edu/courses/15-468/

15-469 Special Topic: Visual Computing Systems

Intermittent: 12 units
Visual computing tasks such as computational imaging, image/video understanding, and real-time graphics are key responsibilities of modern computer systems ranging from sensor-rich smart phones to large datacenters. These workloads demand exceptional system efficiency and this course examines the key ideas, techniques, and challenges associated with the design of parallel, heterogeneous systems that accelerate visual computing applications. This course is intended for graduate and advanced undergraduate-level students interested in architecting efficient graphics, image processing, and computer vision platforms.
Prerequisites: 15-418 or 16-385 or 15-462

15-472 Real-Time Graphics

Intermittent: 12 units
Real-time computer graphics is about building systems that leverage modern CPUs and GPUs to produce detailed, interactive, immersive, and high-frame-rate imagery. Students will build a state-of-the-art renderer using C++ and the Vulkan API. Topics explored will include efficient data handling strategies; culling and scene traversal; multi-threaded rendering; post-processing, depth of field, screen-space reflections; volumetric rendering; sample distribution, spatial and temporal sharing, and anti-aliasing; stereo view synthesis; physical simulation and collision detection; dynamic lights and shadows; global illumination, accelerated raytracing; dynamic resolution, "AI" upsampling; compute shaders; parallax occlusion mapping; tessellation, displacement; skinning, transform feedback; debugging, profiling, and accelerating graphics algorithms.
Prerequisite: 15-462

Course Website: http://graphics.cs.cmu.edu/courses/15-472-s24/

15-473 Visual Computing Systems

Intermittent: 12 units
Visual computing tasks such as computational imaging, image/video understanding, and real-time graphics are key responsibilities of modern computer systems ranging from sensor-rich smart phones to large datacenters. These workloads demand exceptional system efficiency and this course examines the key ideas, techniques, and challenges associated with the design of parallel, heterogeneous systems that accelerate visual computing applications. This course is intended for graduate and advanced undergraduate-level students interested in architecting efficient graphics, image processing, and computer vision platforms.

15-482 Autonomous Agents

Fall: 12 units
Autonomous agents use perception, cognition, actuation, and learning to reliably achieve desired goals, where the agents can be smart homes, mobile robots, intelligent factories, self-driving cars, etc. The goal of this course is to introduce students to techniques needed for developing complete, integrated AI-based autonomous agents. Topics include architectures for intelligent agents; autonomous behaviors, perception, and execution; reasoning under uncertainty; optimization; execution monitoring; machine learning; scheduling; and explanation. A focus of the course will be on the integration and testing of autonomous systems to achieve reliable and robust behavior in the face of sensor noise and uncertainty. The course is project-oriented where small teams of students will design, implement, and evaluate agents that can grow plants autonomously, without human intervention.
Prerequisites: 15-281 or 10-315 or 10-601 or 10-301

Course Website: http://www.cs.cmu.edu/~15482 (http://www.cs.cmu.edu/~15482/)

15-483 Truth, Justice, and Algorithms

Intermittent: 9 units
Truth, Justice, and Algorithms is an interdisciplinary course that covers selected theoretical topics at the interface of computer science and economics, focusing on the algorithmic side of incentives and fairness. The course's topics include: computational social choice, e.g., voting rules as maximum likelihood estimators, the axiomatic approach to ranking systems and crowdsourcing, manipulation of elections and ways to circumvent it; cooperative games, focusing on solution concepts such as the core and the Shapley value, and their computation; fair division algorithms for allocating divisible and indivisible goods, and approximate notions of fairness; online matching algorithms (competitive analysis, not dating) and kidney exchange; noncooperative games, including Nash equilibrium and correlated equilibrium, their computation, connections to learning theory, Stackelberg security games, and the price of anarchy in congestion and routing games; and topics in social networks such as the diffusion of technologies and influence maximization. NOTE: This course is cross-listed with 15-896. Undergraduates may enroll into 15-896 but be aware of work load difference. The two courses are identical in terms of lectures, content, and homework assignments. The only difference is in the final project requirement. In 483, students will prepare a summary of several papers and #8212; this will require 10-20 hours of work. In 896, students will carry out a research project with the goal of obtaining novel results, and present their results in class and #8212; a good project will require 50-60 hours of work. Also note that 483 is 9 units, and 896 is 12 units.
Prerequisite: 15-451 Min. grade C

Course Website: http://www.cs.cmu.edu/~arielpro/15896s16/

15-487 Introduction to Computer Security

Fall: 12 units
This course will introduce students to the fundamentals of computer security and applied cryptography. Topics include software security, networking and wireless security, and applied cryptography. Students will also learn the fundamental methodology for how to design and analyze security critical systems.
Prerequisite: 15-213

15-491 Special Topic: CMRoboBits: AI and Robots for Daily-Life Problems

Fall: 12 units
This course will be a project-based course in which we will look at AI and robotics artifacts and techniques to automate solutions to real-world problems, in particular related to life in cities. The course will start by collecting and brainstorming about real problems biased to ones that involve the physical space in addition to the cyber information space, such as traffic rush hour, noise in cities, 3D building inspection, service and data gathering. We will then formalize the chosen problems and analyze existing real data. The course will proceed by possibly enabling the students to prototype their projects beyond simulation, and using the CORAL lab robots, e.g., the CoBot or NAO robots or drones. The course work will be a single large project, performed by groups of up to 3 students. The projects will be divided in three phases, due at the end of February, March, and the end of the course. Students are expected to have programming experience in C++ or python.
Prerequisite: 15-122 Min. grade C

15-492 Special Topic: Speech Processing

Fall: 12 units
Speech Processing offers a practical and theoretical understanding of how human speech can be processed by computers. It covers speech recognition, speech synthesis and spoken dialog systems. The course involves practicals where the student will build working speech recognition systems, build their own synthetic voice and build a complete telephone spoken dialog system. This work will be based on existing toolkits. Details of algorithms, techniques and limitations of state of the art speech systems will also be presented. This course is designed for students wishing understand how to process real data for real applications, applying statistical and machine learning techniques as well as working with limitations in the technology.
Prerequisite: 15-122 Min. grade C

Course Website: http://www.speech.cs.cmu.edu/15-492/

15-494 Cognitive Robotics: The Future of Robot Toys

Spring: 12 units
This course will explore the future of robot toys by analyzing and programming Anki Cozmo, a new robot with built-in artificial intelligence algorithms. Como is distinguished from earlier consumer robots by its reliance on vision as the primary sensing mode and its sophisticated use of A.I. Its capabilities include face and object recognition, map building, path planning, and object pushing and stacking. Although marketed as a pre-programmed children's toy, Cozmo's open source Python SDK allows anyone to develop new software for it, which means it can also be used for robotics education and research. The course will cover robot software architecture, human-robot interaction, perception, and planning algorithms for navigation and manipulation. Prior robotics experience is not required, just strong programming skills.
Prerequisite: 15-122 Min. grade C

15-495 Topics of Algorithmic Problem Solving

Intermittent: 12 units
This course aims to give implementation motivated perspectives on some algorithmic ideas that fall outside of the scopes of most courses. It is intended for graduate students, as well as undergraduate students who have high grades in 15-210, 15-251, 15-259 (and preferably 15-451). Evaluation will consist of about 30 auto-graded coding tasks, plus either participation in the East Central NA ICPC Regional Contest, or presentations of problem-solving reports from the Chinese IOI Team Selection Camp. The first half of the course will discuss floating point precision, numerical approximation schemes, heuristic search, usage of optimization packages, and vectorization. The second half will provide high-level surveys of 2-D range update and amp; query data structures, proactive propagation, palindromic automata, automated recurrence finding, and maximum adjacency search.
Prerequisites: (21-235 Min. grade C or 15-259 Min. grade C) and 15-210 Min. grade C and 15-251 Min. grade C

15-503 This course is now 15-356 / 856 Introduction to Cryptography

Spring: 9 units
This course is aimed as an introduction to theoretical cryptography for graduate and advanced undergraduate students. We will cover formal definitions of security, as well as constructions of some of the most useful and popular primitives in cryptography: pseudorandom generators, encryption, signatures, zero-knowledge, multi-party computation, etc. In addition, we will cover the necessary number-theoretic background.
Prerequisites: 15-251 Min. grade C and 15-210 Min. grade C

Course Website: http://www.cs.cmu.edu/~goyal/15503.html

15-539 Computer Science Pedagogy

Spring: 9 units
The objective of this course is to build skills in the area of collaborative product design in an educational context. The first part of the course will focus on how to communicate with and engage an audience in an ever-growing virtual environment, using computer science education as the medium. The goal will be to learn how to present information in a creative yet intrinsically pedagogical way. Throughout the course, students will work both independently and in groups to create content for high school students using CMU CS Academy's computer programming curriculum. Contact ecawley@andrew.cmu.edu if you are interested in taking this class as it is special permission only.

15-591 Independent Study in Computer Science

Fall and Spring
The School of Computer Science offers Independent Study courses, which allow motivated students to work on projects under the supervision of a faculty advisor while receiving academic credit. Independent studies are usually one semester in duration and require prior approval from the faculty member and the School of Computer Science.

15-592 Independent Study in Computer Science

Fall and Spring
The School of Computer Science offers Independent Study courses, which allow motivated students to work on projects under the supervision of a faculty advisor while receiving academic credit. Independent studies are usually one semester in duration and require prior approval from the faculty member and the School of Computer Science.

15-593 Independent Study in Computer Science

Fall and Spring
The School of Computer Science offers Independent Study courses, which allow motivated students to work on projects under the supervision of a faculty advisor while receiving academic credit. Independent studies are usually one semester in duration and require prior approval from the faculty member and the School of Computer Science.

15-594 Independent Study in Computer Science

Fall and Spring
The School of Computer Science offers Independent Study courses, which allow motivated students to work on projects under the supervision of a faculty advisor while receiving academic credit. Independent studies are usually one semester in duration and require prior approval from the faculty member and the School of Computer Science.

15-599 SCS Honors Undergraduate Research Thesis

Fall and Spring
Available only to students registered in the CS Senior Research Thesis Program.

15-627 Monte Carlo Methods and Applications

Fall: 9 units
The Monte Carlo method uses random sampling to solve computational problems that would otherwise be intractable, and enables computers to model complex systems in nature that are otherwise too difficult to simulate. This course provides a first introduction to Monte Carlo methods from complementary theoretical and applied points of view, and will include implementation of practical algorithms. Topics include random number generation, sampling, Markov chains, Monte Carlo integration, stochastic processes, and applications in computational science. Students need a basic background in probability, multivariable calculus, and some coding experience in any language.

Course Website: http://www.cs.cmu.edu/~kmcrane/random/

15-635 Foundations of Blockchains

Fall: 12 units
In this course, students will learn the mathematical foundations of blockchains, including how to construct distributed consensus protocols and prove them secure, cryptography for blockchains, and mechanism design for blockchains. This course will take a mathematically rigorous approach. Students are expected to have mathematical maturity and be able to write formal mathematical proofs. Students may also be expected to implement some consensus or cryptographic algorithms. This course is crosslisted with 15-435. Graduate students should take 15-635. Undergraduates should take 15-435.
Prerequisites: 15-210 Min. grade C or 15-251 Min. grade C or 15-330

15-642 Machine Learning Systems

Spring: 12 units
The goal of this course is to provide students an understanding and overview of elements in modern machine learning systems. Throughout the course, the students will learn about the design rationale behind the state-of-the-art machine learning frameworks and advanced system techniques to scale, reduce memory, and offload heterogeneous compute resources. We will also run case studies of large-scale training and serving systems used in practice today. This course offers the necessary background for students who would like to pursue research in the area of machine learning systems or continue to work in machine learning engineering.

15-653 Logic and Mechanized Reasoning

Spring: 12 units
Symbolic logic is fundamental to computer science, providing a foundation for the theory of programming languages, database theory, AI, knowledge representation, automated reasoning, interactive theorem proving, and formal verification. Formal methods based on logic complement statistical methods and machine learning by providing rules of inference and means of representation with precise semantics. These methods are central to hardware and software verification, and have also been used to solve open problems in mathematics. This course will introduce students to logic on three levels: theory, implementation, and application. It will focus specifically on applications to automated reasoning and interactive theorem proving. We will present the underlying mathematical theory, and students will develop the mathematical skills that are needed to design and reason about logical systems in a rigorous way. We will also show students how to represent logical objects in a functional programming language, Lean, and how to implement fundamental logical algorithms. We will show students how to use contemporary automated reasoning tools, including SAT solvers, SMT solvers, and first-order theorem provers to solve challenging problems. Finally, we will show students how to use Lean as an interactive theorem prover.

15-658 Compiler Design

Spring: 15 units
This course covers the design and implementation of compiler and run-time systems for high-level languages, and examines the interaction between language design, compiler design, and run-time organization. Topics covered include syntactic and lexical analysis, handling of user-defined types and type-checking, context analysis, code generation and optimization, and memory management and run-time organization.

Course Website: https://csd.cs.cmu.edu/course-profiles/15-411_611-compiler-design (https://csd.cs.cmu.edu/course-profiles/15-411_611-compiler-design/)

15-668 Physics-Based Rendering

Spring: 12 units
This course is an introduction to physics-based rendering at the advanced undergraduate and introductory graduate level. During the course, we will cover fundamentals of light transport, including topics such as the rendering and radiative transfer equation, light transport operators, path integral formulations, and approximations such as diffusion and single scattering. Additionally, we will discuss state-of-the-art models for illumination, surface and volumetric scattering, and sensors. Finally, we will use these theoretical foundations to develop Monte Carlo algorithms and sampling techniques for efficiently simulating physically-accurate images. Towards the end of the course, we will look at advanced topics such as rendering wave optics, neural rendering, and differentiable rendering.
Prerequisites: 16-385 or 16-720 or 15-462

Course Website: http://graphics.cs.cmu.edu/courses/15-468/

15-669 Special Topics: Visual Computing Systems

Intermittent: 12 units
Visual computing tasks such as computational imaging, image/video understanding, and real-time graphics are key responsibilities of modern computer systems ranging from sensor-rich smart phones to large datacenters. These workloads demand exceptional system efficiency and this course examines the key ideas, techniques, and challenges associated with the design of parallel, heterogeneous systems that accelerate visual computing applications. This course is intended for graduate and advanced undergraduate-level students interested in architecting efficient graphics, image processing, and computer vision platforms.
Prerequisites: 16-385 or 15-462 or 15-418

15-705 Engineering Distributed Systems

Spring: 12 units
This course is for students with strong design and implementation skills who are likely to pursue careers as software architects and lead engineers. It may be taken by well-prepared undergraduates with excellent design and implementation skills in low-level systems programing. The course assumes a high level of proficiency in all aspects of operating system design and implementation. This course will help students prepare for leadership roles in creating and evolving the complex, large-scale computer systems that society will increasingly depend on in the future. The course will teach the organizing principles of such systems, identifying a core set of versatile techniques that are applicable across many system layers. Students will acquire the knowledge base, intellectual tools, hands-on skills and modes of thought needed to build well-engineered computer systems that withstand the test of time, growth in scale, and stresses of live use. Topics covered include: caching, prefetching, damage containment, scale reduction, hints, replication, hash-based techniques, and fragmentation reduction. A substantial project component is an integral part of the course. A high level of proficiency in systems programming is expected. Please refer to course website for the most recent schedule updates.

Course Website: http://www.cs.cmu.edu/~csd-grad/courseschedules14.html

15-719 Advanced Cloud Computing

Spring: 12 units
Computing in the cloud has emerged as a leading paradigm for cost-effective, scalable, well-managed computing. Users pay for services provided in a broadly shared, power efficient datacenter, enabling dynamic computing needs to be met without paying for more than is needed. Actual machines may be virtualized into machine-like services, or more abstract programming platforms, or application-specific services, with the cloud computing infrastructure managing sharing, scheduling, reliability, availability, elasticity, privacy, provisioning and geographic replication This course will survey the aspects of cloud computing by reading about 30 papers and articles, executing cloud computing tasks on a state of the art cloud computing service, and implementing a change or feature in a state of the art cloud computing framework. There will be no final exam, but there will be two in class exams. Grades will be about 50 project work and about 50 examination results.
Prerequisites: 15-213 Min. grade B or 15-513 Min. grade B or 18-213 Min. grade B

Course Website: http://www.cs.cmu.edu/~15719/

15-721 Advanced Database Systems

Intermittent: 12 units
This course is a comprehensive study of the internals of modern database management systems. It will cover the core concepts and fundamentals of the components that are used in large-scale analytical systems (OLAP). The class will stress both efficiency and correctness of the implementation of these ideas.

Course Website: https://15721.courses.cs.cmu.edu

15-749 Post-von Neumann Computer Architecture

Intermittent: 12 units
Computing has been dominated by von Neumann CPU architectures for seventy years. The von Neumann architecture is familiar and flexible, but it is also extremely inefficient, wasting upwards of 99% of energy. As computing is now energy-limited across all scales, from IoT to data center, von Neumann's inefficiency can no longer be tolerated. Recently, industry has adopted heterogeneous "accelerator" hardware to boost performance and efficiency. However, accelerators have limited programmability, sacrificing the main benefit of CPU architectures and putting future innovation at risk. This class will survey non-von Neumann general-purpose architectures, recent work on specialized hardware accelerators, and cutting-edge research on "programmable accelerators".

Course Website: http://www.cs.cmu.edu/~15-749/

15-751 CS Theory Toolkit

Spring: 12 units
This course will take a random walk through various mathematical topics that come in handy for theoretical computer science. It is intended mainly for students earlier in their graduate studies (or very strong undergraduates) who want to do theory research. The idea for the course comes from other courses by Arora (2002, 2007), Håstad (2004/05), Kelner (2007, 2009), and Tulsiani (2013). Students should have a solid undergraduate background in math (e.g., elementary combinatorics, graph theory, discrete probability, basic algebra/calculus) and theoretical computer science (running time analysis, big-O/Omega/Theta, P and NP, basic fundamental algorithms).

Course Website: https://www.cs.cmu.edu/~odonnell/toolkit20 (https://www.cs.cmu.edu/~odonnell/toolkit20/)

15-859 Randomized Algorithms

Fall: 12 units
A graduate-level course on how to use randomization to design algorithms and data structures with strong provable guarantees.

15-883 Computational Models of Neural Systems

Intermittent: 12 units
This course is an in-depth study of information processing in real neural systems from a computer science perspective. We will examine several brain areas, such as the hippocampus and cerebellum, where processing is sufficiently well understood that it can be discussed in terms of specific representations and algorithms. We will focus primarily on computer models of these systems, after establishing the necessary anatomical, physiological, and psychophysical context. There will be some neuroscience tutorial lectures for those with no prior background in this area.

Course Website: http://www.cs.cmu.edu/afs/cs/academic/class/15883-f19/

Human-Computer Interaction Courses

05-090 Human-Computer Interaction Practicum

All Semesters: 3 units
This course is for HCII students who wish to have an internship experience as part of their curriculum. Students are required to write a one-page summary statement prior to registration that explains how their internship connects with their HCI curriculum, specifically on how it uses material they have learned as well as prepares them for future courses. Near the end of the internship, students will be required to submit a reflection paper that describes the work they did in more detail, including lessons learned about the work experience and how they utilized their HCI education to work effectively. International students should consult with the Office of International Education for appropriate paperwork and additional requirements before registration. Units earned count toward the total required units necessary for degree completion; students should speak with an academic advisor for details. This course may be taken at most 3 times for a total of 9 units maximum. Students normally register for this course for use during the summer semester.

05-180 Introduction to Human-Computer Interaction

Spring: 5 units
This course is for first-year students who are interested in learning more about HCI, especially first-year SCS students considering the primary HCI major.

05-200 Ethics and Policy Issues in Computing

Intermittent: 9 units
Should autonomous robots make life and death decisions on their own? Should we allow them to select a target and launch weapons? To diagnose injuries and perform surgery when human doctors are not around? Who should be permitted to observe you, find out who your friends are, what you do and say with them, what you buy, and where you go? Do social media and personalized search restrict our intellectual horizons? Do we live in polarizing information bubbles, just hearing echoes of what we already know and believe? As computing technology becomes ever more pervasive and sophisticated, we are presented with an escalating barrage of decisions about who, how, when, and for what purposes technology should be used. This course will provide an intellectual framework for discussing these pressing issues of our time, as we shape the technologies that in turn shape us. We will seek insight through reading, discussion, guest lectures, and debates. Students will also undertake an analysis of a relevant issue of their choice, developing their own position, and acquiring the research skills needed to lend depth to their thinking. The course will enhance students' ability to think clearly about contentious technology choices, formulate smart positions, and support their views with winning arguments.

05-291 Learning Media Design

Fall: 12 units
[IDeATe collaborative course] Learning is a complex human phenomenon with cognitive, social and personal dimensions that need to be accounted for in the design of technology enhanced learning experiences. In this studio course students will apply learning science concepts to critique existing forms of learning media, establish a set of design precedents to guide project work and produce a series of design concepts that support learning interactions in a real-world context. Collaborating in small interdisciplinary teams, students will partner with a local informal learning organization (e.g. museum, after school program provider, maker space) to conduct learning design research studies, synthesize findings, establish learning goals and iteratively prototype and assess design concepts. As final deliverables, students will present their design research findings, design concepts, and prototypes to stakeholders, and draft a media-rich proposal for their learning media concept to pitch to a local funder. Please note that there may be usage/materials fees associated with this course. Please note that there may be usage/materials fees associated with this course.

05-292 IDeATe: Learning in Museums

Spring: 12 units
Learning in Museums brings together students from across the disciplines to consider the design of mediated learning experiences though a project-based inquiry course. Students will be introduced to a range of design research methods and associated frameworks that explore the cognitive, social and affective dimensions of learning in everyday contexts through readings, invited lectures, in-class activities and assignments. Students will conduct a series of short design research studies to define learning goals and develop supporting design concepts that improve learning outcomes for diverse participants in informal learning settings (e.g. museums, after school programs, maker spaces or online). In concept development, we will look at how to position technology and question its role in the setting to engage and foster positive learning interactions. This course will culminate in a media-rich presentation of design concepts and a prototype to a stakeholder audience, and include an evaluation plan describing how learning outcomes for the project would be assessed.

05-300 HCI Undergraduate Pro Seminar

All Semesters: 2 units
HCI is a broad field that brings together approaches from design, computer science, and psychology. This course provides an introduction to the field of HCI and to the HCI community at CMU. Guest speakers from around campus will provide a general introduction to these approaches and how they are pursued at CMU, and will describe research opportunities that are available to undergraduates. The course will also discuss career options in both industry and academia for students of HCI, and will include presentations from HCI alumni and sessions on preparing resumes, creating portfolios, and interviewing for jobs. The course is designed for current or potential HCI majors and minors but is open to anyone with an interest in applying for the HCI major/minor.

Course Website: https://hcii.cmu.edu/academics/courses (https://hcii.cmu.edu/academics/courses/)

05-315 Persuasive Design

Fall: 12 units
This project-based course focuses on the ethical, human-centered design and evaluation of persuasive technologies that aim to change users' attitudes, emotions, or behaviors in ways that benefit the self and/or society. In addition to exposing students to an array of psychological theories and strategies for implicit and explicit persuasion, the course will cover a variety of topics illustrating both the pitfalls and possibilities in designing for positive impact in HCI. The focal point of the class will be the semester project, for which student teams will iteratively conceptualize, prototype, implement, and evaluate a tool, system, or change to a ubiquitous computing environment that intends to stimulate and sustain belief or behavior change (such as reducing cognitive or social biases, building healthy or prosocial habits, or resisting other persuasive forces one encounters on a daily basis).

05-317 Design of Artificial Intelligence Products

Intermittent: 12 units
This course teaches students how to design new products and services that leverage the capabilities of AI and machine learning to improve the quality of peoples lives. Students will learn to follow a matchmaking design, user-centered design, and service design process. Students will learn to ideate; reframing problematic situations by envisioning many possible products and services. Students will learn to iteratively refine and assess their ideas with real users/customers. Class projects will focus on the challenges of deploying systems that generate errors and the challenges of situating intelligent systems such that they harmonize the best qualities of human and machine intelligence.

Course Website: https://hcii.cmu.edu/academics/courses (https://hcii.cmu.edu/academics/courses/)

05-318 Human AI Interaction

Intermittent: 12 units
Artificial Intelligence is inspired by human intelligence, made powerful by human data, and ultimately only useful in how it positively affects the human experience. This course is an introduction to harnessing the power of AI so that it is beneficial and useful to people. We will cover a number of general topics: agency and initiative, AI and ethics, bias and transparency, confidence and errors, human augmentation and amplification, trust and explainability, mixed-initiative systems, and programming by example. These topics will be explored via projects in dialog and speech-controlled systems, automatic speech recognition, computer vision, data science, recommender systems, text summarization, learning science, UI personalization, and visualization. Students will complete individual weekly mini-projects in which they will design and build AI systems across a wide variety of domains. Students should be comfortable with programming; assignments will be primarily in Python and Javascript. Prior experience with AI/machine learning will be useful but is not required. Students will also be responsible for weekly readings and occasional presentations to the class.

Course Website: http://www.hcii.cmu.edu/academics/courses (http://www.hcii.cmu.edu/academics/courses/)

05-319 Data Visualization

Fall: 12 units
This course is an introduction to key design principles and techniques for interactively visualizing data. The major goals of this course are to understand how visual representations can help in the analysis and understanding of complex data, how to design effective visualizations, and how to create your own interactive visualizations using modern web-based frameworks.

Course Website: https://dig.cmu.edu/courses/2022-fall-datavis.html

05-320 Social Web

Intermittent: 12 units
With the growth of online environments like MySpace, Second Life, World of Warcraft, Wikipedia, blogs, online support groups, and open source development communities, the web is no longer just about information. This course, jointly taught by a computer scientist and a behavioral scientist, will examine a sampling of the social, technical and business challenges social web sites must solve to be successful, teach students how to use high-level tools to analyze, design or build online communities, and help them understand the social impact of spending at least part of their lives online. This class is open to advanced undergraduates and graduate students with either technical or non-technical backgrounds. Course work will include lectures and class discussion, homework, class presentations, and a group research or design project.

05-321 Transformational Game Design Studio

Fall: 12 units
TBA

05-333 Gadgets, Sensors and Activity Recognition in HCI

Fall: 12 units
Recent advances in HCI have been driven by new capabilities to deliver inexpensive devices to users, to display information in mobile and other contexts, to sense the user and their environment, and use these sensors to create models of a user's context and actions. This course will consider both concepts surrounding these new technological opportunities through discussion of current literature - and practical considerations the skills needed to actually build devices. About 1/3 of this class will review current advances in this area. The remainder will be devoted to development of individual skills so that students leaving the class will have an ability to actually build small devices for human interaction (in short: "HCI gadgets"). In particular, the course will concentrate on the basics of building simple microcontroller-based devices and will also provide very basic coverage of the machine learning techniques needed for simple sensor-driven statistical models. The course is designed to be accessible to students with a wide range of backgrounds including both technically-oriented and non-technical students (especially Designers) interested in HCI. The class will be project oriented with 4-5 electronic prototype building projects during the semester. At least two of these projects will be self-defined in nature and can be adapted to the existing skills and interests of each student. There are no formal prerequisites for this class. However, the class will involve programming and debugging of micro-controllers. Some coverage of the language used to do this will be provided, and if required by your background, the programming component of the projects can be made comparatively small (but, in that case some other aspect of the projects will need to be expanded). However, you should not take this course if you have no programming background. This course assumes no background in electronics.

Course Website: http://www.hcii.cmu.edu/courses/applied-gadgets-sensors-and-activity-recognition-hci (http://www.hcii.cmu.edu/courses/applied-gadgets-sensors-and-activity-recognition-hci/)

05-341 Organizational Communication

All Semesters: 9 units
Most of management is communication. You communicate to get information that will be the basis of decisions, coordinate activity, to provide a vision for the people who work for and with you, to and to sell yourself and your work. The goal of this course is to identify communication challenges within work groups and organizations and ways to overcome them. To do this requires that we know how communication normally works, what parts are difficult, and how to fix it when it goes wrong. The focus of this course is on providing you with a broad understanding of the way communication operates within dyads, work groups, and organizations. The intent is to give you theoretical and empirical underpinnings for the communication you will undoubtedly participate in when you move to a work environment, and strategies for improving communication within your groups. Because technology is changing communication patterns and outcomes both in organizations and more broadly in society, the course examines these technological changes. Readings come primarily from the empirical research literature.

Course Website: http://www.hcii.cmu.edu/courses/organizational-communication (http://www.hcii.cmu.edu/courses/organizational-communication/)

05-360 Interaction Design Fundamentals

Fall and Spring: 12 units
IXD Fundamentals introduces the human-centered design process as well as fundamental interaction design principles, methods, and practices. The course is for both students who may only enroll in one interaction design course and those who intend to build upon their HCI learning by taking advanced interaction design courses. Students must work effectively as individuals and in small teams to learn interaction design concepts and apply them to real-world problems. By the end of this course students should be able to; -Apply appropriate interaction design methods in a human-centered design process. -Create persuasive interim and final design artifacts that demonstrate communication design fundamentals. -Facilitate productive and structured critique across the class and with instructors. -Explain and apply fundamental interaction design principles. -Create clarity and readability in artifacts, including GUIs and deliverables, through the disciplined application of visual design principles such as typography, color and composition. -Practice reframing a given problem in order to create opportunities that drive generating multiple solutions. -Demonstrate habits that foster the creative process, including drawing, divergent thinking, and creative experimentation. -Identify and explore with interaction design materials. This course serves as a prerequisite for Advanced Interaction Design Studio (number TBD). Students who are required to take this course have priority and will be enrolled first. No coding is required.

05-361 Advanced Interaction Design

Spring: 12 units
Advanced Interaction Design follows Interaction Design for Human-Computer Interaction (05-360/05-660). Students are expected to build on the basic interaction design principles they learned in Interaction Design Fundamentals by applying advanced methods to solve more complex problems using emerging technologies in user experiences that cross devices, modalities and contexts. Students learn how to design with advanced technologies that predict, assist and automate, and make through a design system. Systems thinking, data as a design material, and UI design are emphasized in projects which are designed to give students experience solving complex problems that they are likely to encounter as practitioners. Advanced Interaction Design prepares students to become interaction designers that take a rigorous and principled approach to solving enterprise-scale problems where many systems and applications serve many stakeholders.
Prerequisites: 05-392 or 05-651 or 05-360

05-380 Prototyping Algorithmic Experiences

Intermittent: 15 units
This project-based course provides an overview and hands-on introduction to iterative prototyping methods in HCI, with an emphasis on current and emerging technologies such as data-driven algorithmic systems, AI and machine learning, spatial computing, and IoT. Students will learn and implement approaches for creating and using prototypes to iteratively inform the creation of new technologies. The course will help students learn to strategically evaluate whether a given prototyping approach is a good fit for a given design or research question. In addition to HCI undergraduate majors, the course is open to undergraduate and graduate level students with proficiency in programming and prior courses or experience in user-centered research, design, and/or evaluation. Some exceptions to the course prerequisites will be granted with permission of the instructor.
Prerequisites: 15-112 and (15-121 or 15-122 or 15-150 or 15-210) and (05-650 or 05-651 or 05-391 or 05-410 or 05-392 or 05-470 or 05-317 or 05-360 or 05-452)

05-391 Designing Human Centered Software

All Semesters: 12 units
"Why are things so hard to use these days? Why doesn't this thing I just bought work? Why is this web site so hard to use? These are frustrations that we have all faced from systems not designed with people in mind. The question this course will focus on is: how can we design human-centered systems that people find useful and usable? This course is a broad introduction to designing, prototyping, and evaluating user interfaces. If you take only one course in Human-Computer Interaction, this is the course for you. We will cover theory as well as practical application of ideas from Human-Computer Interaction. Coursework includes lectures, class discussion, homework, class presentations, and group projects. This class is open to all undergrads and grad students, with either technical or non-technical majors. However, there is a programming prerequisite. "
Prerequisites: 15-112 or 15-110 or 15-122 or 15-104

Course Website: http://www.hcii.cmu.edu/courses/designing-human-centered-software (http://www.hcii.cmu.edu/courses/designing-human-centered-software/)

05-392 Interaction Design Overview

Fall: 9 units
This studio course offers a broad overview of communication and interaction design. Students will learn design methodologies such as brainstorming, sketching, storyboarding, wire framing, and prototyping. Students learn to take a human-centered design approach to their work. Assignments include short in-class exercises as well as individual and team-based projects. Students take part in studio critiques, engaging in critical discussions about the strengths and weaknesses of their own work and the work of others. No coding is required. When registering for this course, undergraduate students are automatically placed the wait list.

05-395 Applications of Cognitive Science

Spring: 9 units
The goal of this course is to examine cases where basic research on cognitive science, including cognitive neuroscience, has made its way into application, in order to understand how science gets applied more generally. The course focuses on applications that are sufficiently advanced as to have made an impact outside of the research field per se; for example, as a product, a change in practice, or a legal statute. Examples are virtual reality (in vision, hearing, and touch), cognitive tutors, phonologically based reading programs, latent semantic analysis applications to writing assessment, and measures of consumers' implicit attitudes. The course will use a case-study approach that considers a set of applications in detail, while building a general understanding of what it means to move research into the applied setting. The questions to be considered include: What makes a body of theoretically based research applicable? What is the pathway from laboratory to practice? What are the barriers - economic, legal, entrenched belief or practice? The format will emphasize analysis and discussion by students. They should bring to the course an interest in application; extensive prior experience in cognitive science is not necessary. The course will include tutorials on basic topics in cognitive science such as perception, memory, and spatial cognition. These should provide sufficient grounding to discuss the applications.

Course Website: http://www.hcii.cmu.edu/courses/applications-cognitive-science (http://www.hcii.cmu.edu/courses/applications-cognitive-science/)

05-410 User-Centered Research and Evaluation

Fall: 12 units
This course provides an overview and introduction to the field of human-computer interaction (HCI). It introduces students to tools, techniques, and sources of information about HCI and provides a systematic approach to design. The course increases awareness of good and bad design through observation of existing technology and teaches the basic skills of generative and evaluative research methods. This is a companion course to courses in visual design (51-422) and software implementation (05-430, 05-431). When registering for this course, undergraduate students are automatically placed the wait list. Students will be then moved into the class, based on if they are in the BHCI second major and year in school e.g. seniors, juniors, etc. In the Fall, this course is NOT open to students outside the HCI major. The Spring offering is open to all students. This course is a core requirement for students in the HCI additional major.
Prerequisites: 85-421 or 85-408 or 85-370 or 85-251 or 85-213 or 85-211 or 85-241 or 88-120

05-413 Human Factors

Fall: 9 units
This course uses theory and research from human factors, cognitive science, and social science to understand and design the interactions of humans with the built world, tools, and technology. The course emphasizes current work in applied domains such as automotive design, house construction, medical human factors, and design of information devices. The course also will emphasize not only individual human factors (e.g., visual response, anthropometry) but also the organizational arrangements that can amplify or correct human factors problems. Through reading, discussion, and projects, you will learn about human perceptual, cognitive, and physical processes that affect how people interact with, and use, technology and tools. You will learn why we have so many automobile accidents, voting irregularities, and injuries from prescription medication. You will learn some tried and true solutions for human factors problems, and some of the many problems in human factors that remain. You will also have gained experience in research in this field.

Course Website: http://www.hcii.cs.cmu.edu

05-417 Computer-mediated Communication

Spring: 6 units
This course examines fundamental aspects of interpersonal communication and considers how different types of computer-mediated communications (CMC) technologies affect communication processes. Among the topics we will consider are: conversational structure and CMC, tools to support nonverbal and paralinguistic aspects of communication such as gesture and eye gaze, and social and cultural dimensions of CMC. Students will be expected to post to weekly discussion lists, to write a paper on a specific aspect of CMC, and to present a talk on their final project to the class. The course should be appropriate for graduate students in all areas and for advanced undergraduates.

05-418 Design Educational Games

Spring: 12 units
The potential of digital games to improve education is enormous. However, it is a significant challenge to create a game that is both fun and educational. In this course, students will learn to meet this challenge by combining processes and principles from game design and instructional design. Students will also learn to evaluate their games for fun, learning, and the integration of the two. They will be guided by the EDGE framework for the analysis and design educational games. The course will involve a significant hands-on portion, in which students learn a design process to create educational games digital or non-digital. They will also read about existing educational games and discuss game design, instructional design, learning and transfer, and the educational effectiveness of digital games. They will analyze an educational game and present their analysis to the class.

Course Website: https://www.hcii.cmu.edu/course/design-of-educational-games (https://www.hcii.cmu.edu/course/design-of-educational-games/)

05-430 Programming Usable Interfaces

Spring: 15 units
This course is combines lecture, and an intensive programming lab and design studio. It is for those who want to express their interactive ideas in working prototypes. It will cover the importance of human-computer interaction/interface design, iterative design, input/output techniques, how to design and evaluate interfaces, and research topics that will impact user interfaces in the future. In lab, you will learn how to design and program effective graphical user interfaces, and how to perform user tests. We will cover a number of prototyping tools and require prototypes to be constructed in each, ranging from animated mock-ups to fully functional programs. Assignments will require implementing UIs, testing that interface with users, and then modifying the interface based on findings. Some class sessions will feature design reviews of student work. This course is for HCII Masters students and HCI dual majors with a minimal programming background. Students will often not be professional programmers, but will need to interact with programmers. RECITATION SELECTION: Students taking this course can sign up for either Prototyping Lab recitation. PREREQUISITES: Proficiency in a programming language, program structure, algorithm analysis, and data abstraction. Normally met through an introductory programming course using C, C++, Pascal or Java, such as 15100, 15112, 15127 or equivalent. Students entering this course should be able to independently write a 300-line program in 48 hours. This course is NOT open to students outside of the BHCI program.
Prerequisites: 15-110 or 15-104 or 15-112 or 15-127 or 15-100

05-431 Software Structures for User Interfaces

Fall: 12 units
This course considers the basic and detailed concepts for building software to implement user interfaces (UIs). It considers factors of input, output, application interface, and related infrastructure as well as the typical patterns used to implement them. It considers how these aspects are organized and managed within a well-structured object oriented system. We will cover a variety of "front-end" programming contexts, including conventional graphical user interface (GUI) programming for mobile apps (phones, watches), web apps, and regular desktop applications, across a variety of frameworks. We will also cover programming for data-driven and conversational (AI) user interfaces. We will briefly touch on front-end programming for visualizations, games, 3D, and virtual and artificial reality (VR and AR), along with interactive UI tools such as prototypers and resource editors. The homeworks and project in this course will involve extensive object-oriented programming, likely in both Java and JavaScript, so this course is only appropriate for students with a strong programming background. Note that this is not an HCI methods course and #8212; we do not cover user-centered design or evaluation methods. This course is designed for students in the SCS HCI undergrad Major, but it also available to any undergrad or graduate student with an interest in the topic and solid prior programming experience who wish to understand the structures needed for professional development of interactive systems. Note that all students who register for this class will initially be placed on a waitlist. Priority for getting into the class are students in the HCII programs (more senior students first), and then others. The graduate (05-631) and undergraduate (05-431) numbers are for the same course with the same work.
Prerequisites: 17-437 or 17-514 or 17-214 or 15-214 or 15-213 or 18-213 or 15-513 or 14-513

05-432 Personalized Online Learning

Fall: 12 units
Online learning has become widespread (e.g., MOOCs, online and blended courses, and Khan Academy) and many claim it will revolutionize higher education and K-12. How can we make sure online learning is maximally effective? Learners differ along many dimensions and they change over time. Therefore, advanced learning technologies must adapt to learners to provide individualized learning experiences. This course covers a number of proven personalization techniques used in advanced learning technologies. One of the techniques is the use of cognitive modeling to personalize practice of complex cognitive skills in intelligent tutoring systems. This approach, developed at CMU, may well be the most significant application of cognitive science in education and is commercially successful. We will also survey newer techniques, such as personalizing based on student meta-cognition, affect, and motivation. Finally, we will look at personalization approaches that are widely believed to be effective but have not proven to be so. The course involves readings and discussion of different ways of personalizing instruction, with an emphasis on cognitive modeling approaches. Students will learn to use the Cognitive Tutor Authoring Tools (CTAT) to implement tutor prototypes that rely on computer-executable models of human problem solving to personalize instruction. The course is meant for graduate or advanced undergraduate students in Human-Computer Interaction, Psychology, Computer Science, Design, or related fields, who are interested in educational applications. Students should either have some programming skills or experience in the cognitive psychology of human problem solving, or experience with instructional design.

Course Website: http://www.hcii.cmu.edu/courses/personalized-online-learning (http://www.hcii.cmu.edu/courses/personalized-online-learning/)

05-433 Programming Usable Interfaces OR Software Structures for Usable Interfaces

Fall: 6 units
Section A: Programming Usable Interfaces Section B: Software Structures for Usable Interfaces This is a lecture-only course (see 05-430/05-630 or 05-431/631 for the lecture + lab version of these courses) that is intended for those who want to learn how to design and evaluate user interfaces. We will cover the importance of human-computer interaction and interface design, the iterative design cycle used in HCI, an overview of input and output techniques, how to design and evaluate interaction techniques, and end with a discussion of hot topics in research that will impact user interfaces in the coming years. This course is only intended for HCII Masters students or HCI undergraduate majors who have already taken an associated User Interface lab, or non-MHCI/BHCI students interested in the design of user interfaces. WAITLIST LOGISTICS: Note that ALL students who register for this class will initially be placed on a waitlist. Your position on the waitlist is not an indication of whether you will be accepted into the class. Contacting the instructor will not move you off the waitlist. Priority for getting off the waitlist are MHCI students, BHCI students (more senior students first), and then others.

05-434 Machine Learning in Practice

Fall and Spring: 12 units
Machine Learning is concerned with computer programs that enable the behavior of a computer to be learned from examples or experience rather than dictated through rules written by hand. It has practical value in many application areas of computer science such as on-line communities and digital libraries. This class is meant to teach the practical side of machine learning for applications, such as mining newsgroup data or building adaptive user interfaces. The emphasis will be on learning the process of applying machine learning effectively to a variety of problems rather than emphasizing an understanding of the theory behind what makes machine learning work. This course does not assume any prior exposure to machine learning theory or practice. In the first 2/3 of the course, we will cover a wide range of learning algorithms that can be applied to a variety of problems. In particular, we will cover topics such as decision trees, rule based classification, support vector machines, Bayesian networks, and clustering. In the final third of the class, we will go into more depth on one application area, namely the application of machine learning to problems involving text processing, such as information retrieval or text categorization. 05-834 is the HCII graduate section. If you are an LTI student, please sign up for the LTI graduate course number (11-663) ONLY to count properly towards your degree requirements. 05-434 is the HCII undergraduate section. If you are an LTI student, please sign up for the LTI undergraduate course number (11-344) ONLY to count properly towards your degree requirements.

Course Website: http://www.hcii.cmu.edu/courses/applied-machine-learning (http://www.hcii.cmu.edu/courses/applied-machine-learning/)

05-435 Applied Fabrication for HCI

Fall: 12 units
This course will consider how new fabrication techniques such as 3D printing, laser cutting, CNC machining and related computer controlled technologies can be applied to problems in Human-Computer Interaction. Each offering will concentrate on a particular application domain for its projects. This year the course will consider assistive technology. This course will be very hands-on and skills-oriented, with the goal of teaching students the skills necessary to apply these technologies to HCI problems such as rapid prototyping of new device concepts. To this end? Every student in this course will build and take home a 3D printer. (There will be $400-$500 cost associated with this course to make that possible. Details on this are still to be determined.)

05-436 Usable Privacy and Security

Spring: 9 units
There is growing recognition that technology alone will not provide all of the solutions to security and privacy problems. Human factors play an important role in these areas, and it is important for security and privacy experts to have an understanding of how people will interact with the systems they develop. This course is designed to introduce students to a variety of usability and user interface problems related to privacy and security and to give them experience in designing studies aimed at helping to evaluate usability issues in security and privacy systems. The course is suitable both for students interested in privacy and security who would like to learn more about usability, as well as for students interested in usability who would like to learn more about security and privacy. Much of the course will be taught in a graduate seminar style in which all students will be expected to do a weekly reading assignment and each week different students will prepare a presentation for the class. Students will also work on a group project throughout the semester. The course is open to all graduate students who have technical backgrounds. The 12-unit course numbers (08-734 and 5-836) are for PhD students and masters students. Students enrolled in these course numbers will be expected to play a leadership role in a group project that produces a paper suitable for publication. The 9-unit 500-level course numbers (08-534 and 05-436) are for juniors, seniors, and masters students. Students enrolled in these course numbers will have less demanding project and presentation requirements.

Course Website: http://www.hcii.cmu.edu/courses/usuable-privacy-and-security (http://www.hcii.cmu.edu/courses/usuable-privacy-and-security/)

05-439 The Big Data Pipeline: Collecting and Using Big Data for Interactive Systems

Spring: 12 units
This course covers techniques and technologies for creating data driven interfaces. You will learn about the entire data pipeline from sensing to cleaning data to different forms of analysis and computation.

Course Website: http://data.cmubi.org

05-440 Interaction Techniques

Intermittent: 12 units
This course will provide a comprehensive study of the many ways to interact with computers and computerized devices. An "interaction technique" starts when the user does something that causes an electronic device to respond and includes the direct feedback from the device to the user. Examples include physical buttons and switches, on-screen menus and scroll bars operated by a mouse, touch screen widgets and gestures such as flick-to-scroll, text entry on computers or touch screens, game controllers, interactions in 3D and virtual/augmented reality, consumer electronic controls such as remote controls, and adaptations of all of these for people with disabilities. We will start with a history of the invention and development of these techniques, discuss the various options used today, and continue on to the future with the latest research on interaction techniques presented at conferences such as ACM CHI and UIST. Appropriate design and evaluation methods for interaction techniques will also be covered. Guest lectures from inventors of interaction techniques are planned. Students will have a choice for final projects that can focus on historical or novel interaction techniques.

Course Website: http://www.cs.cmu.edu/~bam/uicourse/05440inter/

05-452 Service Design

Fall: 12 units
In this course, we will collectively define and study services and product service systems, and learn the basics of designing them. We will do this through lectures, studio projects, and verbal and written exposition. Classwork will be done individually and in teams.

05-470 Digital Service Innovation

Intermittent: 12 units
Attention entrepreneurs, designers, and engineers! This course teaches you to invent digital services. You will learn about value-creation in the service sector and a human-centered design process including brainstorming, story-boarding, interviewing, video sketches, and pitching. Students work in small, interdisciplinary teams to discover unmet needs of users. They conceive of a digital service and assess its technical feasibility, financial viability, and desirability. Then they produce a plan with a business model and a video sketch and pitch it to industry professionals. Grades will be determined primarily by the quality of the team's products.

Course Website: https://www.hcii.cmu.edu/course/digital-service-innovation (https://www.hcii.cmu.edu/course/digital-service-innovation/)

05-499 Special Topics in HCI

Fall and Spring: 12 units
Special Topics in HCI is an opportunity for students interested in HCI to gain a deeper understanding of a specific area in this field. Each class is designed to cover an emerging research area within HCI, from designing large-scale peer learning systems to designing games around audience agency. All sections will help students: (1) build a more comprehensive understanding of an area of study within HCI, (2) work closely with faculty and peers to create mini-projects or team assignments that help students master the course material, (3) explore evidence-based research methods and techniques in HCI. Sections will vary in topic and often change from semester to semester. Because of this, students can take multiple sections, as they are individual classes. Undergraduate sections are listed as 499 and graduate sections are listed as 899. For descriptions of specific sections for this academic year, visit the "Courses" section on the Human-Computer Interaction Institute website.

Course Website: http://www.hcii.cmu.edu/academics/courses (http://www.hcii.cmu.edu/academics/courses/)

05-540 Rapid Prototyping of Computer Systems

Spring: 12 units
This is a project-oriented course, which will deal with all four aspects of project development: the application, the artifact, the computer-aided design environment, and the physical prototyping facilities. The class consists of students from different disciplines who must synthesize and implement a system in a short period of time. Upon completion of this course the student will be able to: generate systems specifications from a perceived need; partition functionality between hardware and software; produce interface specifications for a system composed of numerous subsystems; use computer-aided development tools; fabricate, integrate, and debug a hardware/software system; and evaluate the system in the context of an end user application. The class consists of students from different disciplines who must synthesize and implement a system in a short period of time.

Course Website: http://www.hcii.cmu.edu/courses/rapid-prototyping-computer-systems (http://www.hcii.cmu.edu/courses/rapid-prototyping-computer-systems/)

05-571 Undergraduate Project in HCI

Spring: 12 units
Experiential learning is a key component of the MHCI program. Through a substantial team project, students apply classroom knowledge in analysis and evaluation, implementation and design, and develop skills working in multidisciplinary teams. Student teams work with Carnegie Mellon University-based clients or external clients to iteratively design, build and test a software application which people directly use.
Prerequisites: 05-631 Min. grade B or 05-410 Min. grade B or 05-430 Min. grade B or 05-431 Min. grade B or 05-610 Min. grade B or 05-630 Min. grade B

Course Website: http://www.hcii.cmu.edu/courses/undergraduate-project-hci (http://www.hcii.cmu.edu/courses/undergraduate-project-hci/)

05-589 Independent Study in HCI-UG

All Semesters
In collaboration with and with the permission of the professor, undergraduate students may engage in independent project work on any number of research projects sponsored by faculty. Students must complete an Independent Study Proposal, negotiate the number of units to be earned, complete a contract, and present a tangible deliverable. The Undergraduate Program Advisor's signature is required for HCI undergraduate-level Independent Study courses. Registration is through the HCII Undergraduate Programs Manager only.

05-600 HCI Pro Seminar

Fall: 6 units
This course is only for MHCI students. This course is specifically built to expose students to the world of HCI through research and industry talks, as well as strengthening HCI communication skills for work in industry. Seminar Component:To expose students to the world of HCI through research and industry expert talks with written assignments. Conflict Management Component:To educate students on conflict management, teamwork, active listening skills, and communication skills in order to give them tools to collaborate and work more efficiently on multi-disciplinary teams. Professional Series Component: To expose students to the world of HCI through guest speakers, prepare students to navigate job hunting through resume and portfolio workshops and to provide industry insights into HCI and the profession through guest speakers and panel discussions.

Course Website: http://www.hcii.cs.cmu.edu

05-602 IDeATe: Learning in Museums

Spring: 12 units
Learning in Museums brings together students from across the disciplines to consider the design of mediated learning experiences in a project-based inquiry course. Students will be introduced to a range of design research methods and associated frameworks that explore the cognitive, social and affective dimensions of learning in everyday contexts through readings, invited lectures, in-class activities and assignments. Students will conduct a series of short design research studies to define learning goals and develop supporting design concepts intended to improve learning outcomes for diverse participants in informal learning settings (e.g. museums, after-school programs, maker spaces or online). In concept development, we will look at how to position technology and question its role in the setting to engage and foster positive learning interactions and conversation. This semester we will be working with the Carnegie Museum of Natural History as our primary stakeholder. The course will culminate in a media-rich presentation of design concepts and a fielded prototype to a review panel and include a piloted evaluation plan describing how learning outcomes for the project would be assessed. In consultation with the instructor, students in the graduate section of the course will be assigned an HCI/learning research literature review and presentation related to their project topic.

05-610 User-Centered Research and Evaluation

Fall: 12 units
This course provides and overview and introduction to the field of human-computer interaction (HCI). It introduces students to tools, techniques, and sources of information about HCI and provides a systematic approach to design. The course increases awareness of good and bad design through observation of existing technology, and teaches the basic skills of generative and evaluative research methods. This is a companion course to software implementation (05-430, 05-431 05-380). When registering for this course, undergraduate students are automatically placed the wait list. Students will be then moved into the class, based on if they are in the BHCI primary or second major and year in school e.g. seniors, juniors, etc. Freshman are not permitted to register in this course. In the Fall, this course is NOT open to students outside the HCI major or MHCI. The Spring offering is open to all students. This course is a core requirement for students in the HCI additional major and the MHCI program.
Prerequisites: 85-213 or 85-211 or 85-241 or 88-120 or 85-370 or 85-408 or 85-421 or 85-251

Course Website: http://www.hcii.cs.cmu.edu

05-615 Persuasive Design

Fall: 12 units
This project-based course focuses on the ethical, human-centered design and evaluation of persuasive technologies that aim to change users' attitudes, emotions, or behaviors in ways that benefit the self and/or society. In addition to exposing students to an array of psychological theories and strategies for implicit and explicit persuasion, the course will cover a variety of topics illustrating both the pitfalls and possibilities in designing for positive impact in HCI. The focal point of the class will be the semester project, for which student teams will iteratively conceptualize, prototype, implement, and evaluate a tool, system, or change to a ubiquitous computing environment that intends to stimulate and sustain belief or behavior change (such as reducing cognitive or social biases, building healthy or prosocial habits, or resisting other persuasive forces one encounters on a daily basis).

05-618 Human AI Interaction

Intermittent: 12 units
Artificial Intelligence is inspired by human intelligence, made powerful by human data, and ultimately only useful in how it positively affects the human experience. This course is an introduction to harnessing the power of AI so that it is beneficial and useful to people. We will cover a number of general topics: agency and initiative, AI and ethics, bias and transparency, confidence and errors, human augmentation and amplification, trust and explainability, mixed-initiative systems, and programming by example. These topics will be explored via projects in dialog and speech-controlled systems, automatic speech recognition, computer vision, data science, recommender systems, text summarization, learning science, UI personalization, and visualization. Students will complete individual weekly mini-projects in which they will design and build AI systems across a wide variety of domains. Students should be comfortable with programming; assignments will be primarily in Python and Javascript. Prior experience with AI/machine learning will be useful but is not required. Students will also be responsible for weekly readings and occasional presentations to the class.

Course Website: https://www.hcii.cmu.edu/academics/courses (https://www.hcii.cmu.edu/academics/courses/)

05-619 Data Visualization

Fall: 12 units
This course is an introduction to key design principles and techniques for interactively visualizing data. The major goals of this course are to understand how visual representations can help in the analysis and understanding of complex data, how to design effective visualizations, and how to create your own interactive visualizations using modern web-based frameworks.

Course Website: https://dig.cmu.edu/courses/2022-fall-datavis.html

05-650 Interaction Design Studio II

Spring: 12 units
This course follows Interaction Design Fundamentals (05-651). Students are expected to apply what they have learned about design thinking and methodologies as a starting point for all assignments. Students will work in teams to perform guerrilla research, synthesize data, and consider the needs of multiple stakeholders in their design of mobile services and other intelligent systems. Design concepts go beyond user interfaces to include sensors, controls, and ubiquitous computing. Emphasis is placed on the quality of the students ideas and their ability to give form to their design concepts. By completing and presenting their work, students will gain skills related to professional UX design practice.
Prerequisite: 05-651

Course Website: http://www.hcii.cmu.edu/courses/interaction-design-studio (http://www.hcii.cmu.edu/courses/interaction-design-studio/)

05-651 Interaction Design Studio 1

Fall: 12 units
This studio course introduces students to design thinking and the basic practices of interaction design. We follow a human-centered design process that includes research, concept generation, prototyping, and refinement. Students must work effectively as individuals and in small teams to design mobile information systems and other interactive experiences. Assignments approach design on three levels: specific user interactions, contexts of use, and larger systems. Students will become familiar with design methodologies such as sketching, storyboarding, wire framing, prototyping, etc. No coding is required. This course serves as a prerequisite for Interaction Design Studio (05-650). Students who are required to take this course have priority and will be enrolled first.

05-660 Interaction Design Fundamentals

Fall and Spring: 12 units
IXD Fundamentals introduces the human-centered design process as well as fundamental interaction design principles, methods, and practices. The course is for both students who may only enroll in one interaction design course and those who intend to build upon their HCI learning by taking advanced interaction design courses. Students must work effectively as individuals and in small teams to learn interaction design concepts and apply them to real-world problems. By the end of this course students should be able to; -Apply appropriate interaction design methods in a human-centered design process. -Create persuasive interim and final design artifacts that demonstrate communication design fundamentals. -Facilitate productive and structured critique across the class and with instructors. -Explain and apply fundamental interaction design principles. -Create clarity and readability in artifacts, including GUIs and deliverables, through the disciplined application of visual design principles such as typography, color and composition. -Practice reframing a given problem in order to create opportunities that drive generating multiple solutions. -Demonstrate habits that foster the creative process, including drawing, divergent thinking, and creative experimentation. -Identify and explore with interaction design materials. This course serves as a prerequisite for Advanced Interaction Design Studio (number TBD). Students who are required to take this course have priority and will be enrolled first. No coding is required.

05-661 Advanced Interaction Design

Spring: 12 units
Advanced Interaction Design (05-361/05-661) follows Interaction Design for Human-Computer Interaction (05-360/05-660). Students are expected to build on the basic interaction design principles they learned in Interaction Design Fundamentals by applying advanced methods to solve more complex problems using emerging technologies in user experiences that cross devices, modalities and contexts. Students learn how to design with advanced technologies that predict, assist and automate, and make through a design system. Systems thinking, data as a design material, and UI design are emphasized in projects which are designed to give students experience solving complex problems that they are likely to encounter as practitioners. Advanced Interaction Design prepares students to become interaction designers that take a rigorous and principled approach to solving enterprise-scale problems where many systems and applications serve many stakeholders.
Prerequisites: 05-651 or 05-692 or 05-660

05-670 Digital Service Innovation

Fall: 12 units
Attention entrepreneurs, designers, and engineers! This course teaches you to invent digital services. You will learn about value-creation in the service sector and a human-centered design process including brainstorming, story-boarding, interviewing, video sketches, and pitching. Students work in small, interdisciplinary teams to discover unmet needs of users. They conceive of a digital service and assess its technical feasibility, financial viability, and desirability. Then they produce a plan with a business model and a video sketch and pitch it to industry professionals. Grades will be determined primarily by the quality of the team's products.

Course Website: https://www.hcii.cmu.edu/course/digital-service-innovation (https://www.hcii.cmu.edu/course/digital-service-innovation/)

05-674 Ethics and Policy Issues in Computing

Intermittent: 9 units
Should autonomous robots make life and death decisions on their own? Should we allow them to select a target and launch weapons? To diagnose injuries and perform surgery when human doctors are not around? Who should be permitted to observe you, find out who your friends are, what you do and say with them, what you buy, and where you go? Do social media and personalized search restrict our intellectual horizons? Do we live in polarizing information bubbles, just hearing echoes of what we already know and believe? As computing technology becomes ever more pervasive and sophisticated, we are presented with an escalating barrage of decisions about who, how, when, and for what purposes technology should be used. This course will provide an intellectual framework for discussing these pressing issues of our time, as we shape the technologies that in turn shape us. We will seek insight through reading, discussion, guest lectures, and debates. Students will also undertake an analysis of a relevant issue of their choice, developing their own position, and acquiring the research skills needed to lend depth to their thinking. The course will enhance students' ability to think clearly about contentious technology choices, formulate smart positions, and support their views with winning arguments.

05-680 Independent Study in HCI - METALS

All Semesters
With the permission of the professor, METALS students may engage in independent project work on any number of innovative research projects sponsored by faculty. Students must complete an Independent Study Proposal, negotiate the number of units to be earned, submit a contract, and present a tangible deliverable. The Program Advisor's signature is required for the METALS Independent Study course.

05-685 Prototyping Algorithmic Experiences

Intermittent: 15 units
This project-based, technical studio course provides an overview and hands-on introduction to iterative prototyping methods in HCI. Students learn methods and strategies to iteratively prototype novel technologies with users. Students will practice strategically evaluating whether a given prototyping approach is a good fit for a given design or research question (e.g., in terms of expected time, effort, and informativeness). Through a series of rapid course projects, students will explore the cutting-edge of HCI methods for prototyping complex interactive experiences with challenging design materials, such as AI and machine learning, social computing, and spatial computing. In addition to HCI undergraduate majors, the course is open to undergraduate and graduate level students with proficiency in programming and prior courses or experience in user-centered research, design, and/or evaluation. Some exceptions to the course prerequisites will be granted with permission of the instructor.
Prerequisites: 15-112 and (15-210 or 15-150 or 15-122 or 15-121) and (05-891 or 05-651 or 05-650 or 05-652 or 05-610 or 05-617 or 05-660 or 05-392 or 05-670)

05-738 Evidence-Based Educational Design

Fall: 12 units
In this course, we will explore the essential principles of educational design, focusing on creating inclusive environments for diverse learners and promoting positive behavior. We will explore effective strategies for measuring learning outcomes, enhancing student engagement, and assessing educational effectiveness. Students will prepare for careers as instructional designers, learning engineers, educators, and researchers as we cover the range of topics in this class. The coursework includes a thorough examination of current research in learning sciences through various papers and textbooks. Additionally, students will apply these theoretical principles practically by completing two hands-on projects, seeing the direct application of the concepts to real-world use cases. Class time will be spent discussing the weekly readings, highlighting relevant case studies, and engaging in group activities that foster collaboration and practical application of the material covered. This course will prepare students for real-world challenges in educational design and help integrate learning science knowledge through practical experience, enabling them to create effective educational designs and strategies.

05-823 E-Learning Design Principles and Methods

Fall: 12 units
Good design is a continuous improvement process that combines scientific principles and data-driven methods to achieve desired outcomes. E-learning design is no exception. In this course, you will learn how to design innovative e-learning, that is, online interactions and technology that make learning more effective and efficient. You will practice instructional design using learning science theories and principles and learning engineering using data-driven methods to discover insights about how learners think. Instructional designers explain and use principles of learning and instruction such as proven ways to support learning-by-doing, like deliberate practice and self-explanation, and proven ways to support multimedia learning from text, visuals, and audio. They employ "backward design": designing and aligning learning goals, the assessments that measure them, and the instruction that achieves them. But today's learning engineers do not simply design in sequence and #8212; goals then assessments then instruction and #8212; but are agile and iterative. They collect qualitative data, for example, by having an expert "think aloud" while performing one of their assessments and use the results to add or change goals. They collect and use quantitative data, for example, by mining learning data from online course interactions or by comparing alternative designs in an A/B experiment. By using data, learning engineers create innovative and effective designs unlike the results of others who rely on science and intuition alone. You will do so too in an end-to-end e-learning design project, where you develop an e-learning module of your choice, continuously improve it, and test it in an A/B experiment.

Course Website: https://www.hcii.cmu.edu/course/e-learning-design-principles (https://www.hcii.cmu.edu/course/e-learning-design-principles/)

05-839 Interactive Data Science

Spring: 12 units
This course covers techniques and technologies for creating data driven interfaces. You will learn about the entire data pipeline from sensing to cleaning data to different forms of analysis and computation.

Course Website: https://hcii.cmu.edu/academics/courses (https://hcii.cmu.edu/academics/courses/)

05-840 Tools for Online Learning

Fall: 12 units
In this course, we will explore issues that pertain to interaction and interface design. The class will focus on elements of the larger interaction design process including basic design principles, information architecture and navigation, planning and brainstorming methods, and techniques for developing rapid sketches and prototypes. Course Requirements: This class will not focus on learning specific software tools. Students are expected to have prior experience using a variety of design and programming tools. Please speak with the instructor if you have questions regarding these prerequisites. This course was design for students in the METALS program.

Software Societal Systems Courses

17-200 Ethics and Policy Issues in Computing

Fall and Spring: 9 units
Should autonomous robots make life and death decisions on their own? Should we allow them to select a target and launch weapons? To diagnose injuries and perform surgery when human doctors are not around? Who should be permitted to observe you, find out who your friends are, what you do and say with them, what you buy, and where you go? Do social media and personalized search restrict our intellectual horizons? Do we live in polarizing information bubbles, just hearing echoes of what we already know and believe? As computing technology becomes ever more pervasive and sophisticated, we are presented with an escalating barrage of decisions about who, how, when, and for what purposes technology should be used. This course will provide an intellectual framework for discussing these pressing issues of our time, as we shape the technologies that in turn shape us. We will seek insight through reading, discussion, guest lectures, and debates. Students will also undertake an analysis of a relevant issue of their choice, developing their own position, and acquiring the research skills needed to lend depth to their thinking. The course will enhance students' ability to think clearly about contentious technology choices, formulate smart positions, and support their views with winning arguments.

17-210 Introduction to Social Networks

Spring: 12 units
Course Description What makes a recommendation system on social media effective? Why do YouTube mega-influencers with tens of millions of subscribers exist, yet we have not heard of most of them? Why do echo chambers form and polarization deepen in social media platforms despite the utopian promise of the free flow of information and fluid connectivity between people that these platforms had envisioned? How do professionals land their dream jobs? How does mass adoption of technological innovations happen (e.g., Python, Bitcoin)? Underlying these seemingly unrelated questions is the powerful influence of social networks, the collection of social connections that people form on and offline. This course offers an introduction to the study of social networks as a powerful tool for understanding a wide range of questions and for solving real-world problems arising at the intersection of human social behavior and technological systems. The course first introduces network concepts and their mathematical operationalizations that give social network analysis the versatility for rigorous quantitative analysis. Students will subsequently learn how these building blocks have been applied to analyze and solve a wide range of online social phenomena. Finally, the course will introduce statistical models of networks that enable principled investigation of network formation mechanisms. Throughout this course, students will work towards a final team project that applies network concepts and measures to either (a) describe and/or explain an empirically puzzling social phenomenon with network data, (b) develop a network data collection pipeline that aims to solve a real-world problem, or (c) build a system utiziling the insights from the course that solves a real-world problem. The following class activities throughout the course are intended to support and augment the final project.

17-213 Network Analysis: The Hidden Structures behind the Webs We Weave

Fall: 12 units
Have you wondered how Linux and the subsequent development of open-source software ecosystems could thrive despite weak economic incentives? Why do large-scale complex software systems sometimes fail despite well-developed guardrails and practices? What makes a recommendation system on social media so effective and so toxic at the same time? Why do YouTube mega-influencers with tens of millions of subscribers exist, yet each of us only recognize a handful of them at best? Why do echo chambers form and polarization deepen in social media platforms despite the utopian promise of frictionless connectivity that these platforms initially envisioned? How can you land your dream jobs? How does mass adoption of technological innovations happen (e.g., Python, Bitcoin)? Underlying these seemingly unrelated questions is the powerful influence of social networks, the collection of on- and offline social connections, communications, and collaborations that people form with one another. This course offers an introduction to the study of social networks as a powerful tool for formalizing these wide range of questions, for understanding social dynamics in various settings, and for solving real-world problems arising at the intersection of human social behavior and technological systems. The course first introduces network science concepts and their mathematical operationalizations that give rigorous definitions to fuzzy words we use to describe the social world, such as "status" and "social group". Students will subsequently learn how these network concepts were used to analyze and solve a wide range of puzzling online social phenomena. Finally, the course will introduce statistical models of networks that enable principled investigation of network formation mechanisms.

17-214 Principles of Software Construction: Objects, Design, and Concurrency

Fall and Spring: 12 units
Software engineers today are less likely to design data structures and algorithms from scratch and more likely to build systems from library and framework components. In this course, students engage with concepts related to the construction of software systems at scale, building on their understanding of the basic building blocks of data structures, algorithms, and program and computer structures. The course covers technical topics in four areas: (1) concepts of design for complex systems, (2) object-oriented programming, (3) static and dynamic analysis for programs, and (4) concurrency. At the conclusion of this course, students will have substantial experience building medium-sized software systems in Java or JavaScript.
Prerequisites: (15-122 Min. grade C or 15-121 Min. grade C) and (15-151 Min. grade C or 21-127 Min. grade C or 21-128 Min. grade C)

Course Website: https://www.cs.cmu.edu/~ckaestne/17214/f2021/

17-224 Influence, Persuasion, and Manipulation Online

Fall: 9 units
This course will introduce the fundamental behavioral science of influence, persuasion, and manipulation, and the application of these scientific principles to online campaigns to influence attitudes and behavior. In particular, we will discuss the psychology of persuasion, nudging, social influence, bias, persuasive design, and the ethics of persuasion. Against this background, we will analyze case studies drawn from recent, high profile events such as election campaigns, targeted advertising, sowing political division, memes and virality, impact of social media, and propagation of "fake news." Countermeasures to these tactics will be explored, including personal measures, technologies, and policy.

17-301 Special Topics in Societal Computing: Understanding Cyber Teams

Fall: 9 units
Were you the victim of a ransomware attack today? No? Then you should probably thank your cyber security team! Nowadays, nearly everything modern organizations do is protected by some semblance of a cyber team. These cyber teams come in many forms: security operations center, malware analysis, threat emulation, information technology departments, etc. So what do we know about how these cyber teams operate? In this course cyber teams will be studied through the lens of computational organization theory. Different types of cyber teams will be presented with how they operate within the organization. An array of computational organization theory principles will be explored such as network science, information diffusion, policy analysis, and performance theory. A final project will be completed by each student. This project can be of many types such as policy analysis, virtual experimentation, dynamic network analysis, validation, etc. Students will be using the NetLogo scripting language to complete a project. The project will be created, developed, and presented by the student and approved by the instructor.

17-302 Independent Study Mini Undergraduate

Intermittent
Independent Study Mini

17-303 Cryptocurrencies, Blockchains and Applications

Fall and Spring: 9 units
Cryptocurrencies such as Bitcoin have gained large popularity in recent years, in no small part due to the fantastic potential applications they could facilitate. This course will first provide an overview of the technological mechanisms behind cryptocurrencies and distributed consensus and distributed ledgers ("blockchains"), introducing along the way the necessary cryptographic tools. It will then focus on more advanced blockchain applications, such as "smart contracts," that is, contracts written as code. Finally, the course will also introduce some of the legal and policy questions surrounding cryptocurrencies.

17-313 Foundations of Software Engineering

Fall and Spring: 12 units
Students gain exposure to the fundamental principles of software engineering. This includes both core CS technical knowledge and the means by which this knowledge can be applied in the practical engineering of complex software in real-world settings. Topics related to software artifacts include coding, software architecture, measurement, and quality assurance of various qualities (e.g., robustness, security, performance, maintainability) with static and dynamic analysis, testing, code review, and inspection. Topics related to software process include requirements engineering, process models and evaluation, personal and team development, and supply chain issues including outsourcing and open source. This course has a strong technical focus, a strong focus on developing team skills, and will include both written and programming assignments. Students will get experience with the latest software engineering tools and practices.
Prerequisites: 15-121 or 15-122

Course Website: https://www.cs.cmu.edu/~ckaestne/17313/

17-314 Formal Methods

Fall: 6 units
Scientific foundations for software engineering depend on the use of precise, abstract models for describing and reasoning about properties of software systems. This course considers a variety of standard models for representing sequential and concurrent systems, such as state machines, algebras, and traces. It shows how different logics can be used to specify properties of systems, such as functional correctness, deadlock freedom, and internal consistency. Concepts such as compositionality, abstraction, invariants, non-determinism, and inductive definitions are recurrent themes throughout the course. After completing this course, students will: 1. Understand the strengths and weaknesses of certain models and logics including state machines, algebraic and process models, and temporal logic; 2. Be able to select and describe appropriate abstract formal models for certain classes of systems, describe abstraction relations between different levels of description, and reason about the correctness of refinements; 3. Be able to prove elementary properties about systems described by the models introduced in the course; and 4. Understand some of the strengths and weakness of formal automated reasoning tools. Prerequisites: Undergraduate discrete math including first-order logic, sets, functions, relations, and simple proof techniques such as induction.

17-320 Machine Learning and Sensing for Healthcare

Fall: 12 units
Today's health infrastructure makes it challenging for individuals to equitably access even basic medical resources. In this course, we will learn how to create modern health sensing systems that reimagine the way that healthcare delivery is performed. Specifically, we will learn how to transform ubiquitous smart devices around us like smartphones, speakers, and watches, as well as emerging wearables like earables and smartglasses, into personal medical tricorders that have the ability to provide access to health testing at our fingertips. We will learn how to tap into the rich sensor data streams (e.g. acoustic, vision, IMU) from these devices and understand core techniques in applied signal processing and machine learning to intelligently transform sensor data into clinically-relevant biomarkers which can be used to screen and diagnose diseases at scale. Beyond these techniques, this course delves into the full lifecycle of system building including ideation of frugal designs, iterative prototyping, pilot data collection, visualization, and debugging. Finally, to ensure our systems will have impact in the real-world we will cover important issues of privacy-preserving techniques and regulatory pathways which are important considerations when deploying health research. The course will focus on class discussions, hands-on demonstrations, and tutorials. Students will be evaluated on their class participation, multiple mini projects, and a final team project.

Course Website: https://docs.google.com/spreadsheets/d/1OoZfohCyawAkynDMAQD3k9nH6hHvJ8vueVurtuZs0vo/edit?usp=sharing (https://docs.google.com/spreadsheets/d/1OoZfohCyawAkynDMAQD3k9nH6hHvJ8vueVurtuZs0vo/edit/?usp=sharing)

17-322 Agile Methods

Fall: 6 units
Agile methods refers to a number of software development approaches that adopt self-organization, adaptive planning, evolutionary development, frequent delivery and working closely with and incorporating feedback from customers throughout the development process as their principles of operation to achieve responsiveness. This course will introduce students to two well known agile methods: Scrum and Kanban, connecting their practices to established group dynamics and knowledge management theories to explain why they work and under what circumstances

17-323 Quality Assurance

Fall: 6 units
This class is fundamentally about software quality assurance and control. This course will introduce various quality assurance tools and techniques to software engineering students. Students will build their "quality toolbox" not only with useful tools and techniques, but with the knowledge of when those tools should be used, how to evaluate their results, and what assurances they can provide. The key learning objectives of the course include: 1. Understand software quality: how to define it, analyze it, and measure it. 2. Select the proper analytical tool/technique for a given situation and explore how to analyze results. 3. Understand the strengths and weaknesses of different quality assurance techniques, such as software testing, static analysis, code review, and demonstration. 4. Learn to collect, manage, and evaluate quality metrics. 5. Analyze and verify a variety of software properties including, but not limited to, functionality, security, reliability, and performance. 6. Gain experience with real quality assurance tools including static analysis tools, software testing frameworks, and software quality measurement tools

17-324 Advanced Formal Methods

Fall: 6 units
This course builds on the introductory Models class to cover more advanced techniques for modeling and reasoning about complex software systems. Concepts introduced in this course include abstraction and refinement, declarative specifications, advanced temporal logics, and probabilistic modeling. The course will also explore applications of modeling and automated reasoning techniques in various domains, such as security, distributed computing, and cyber-physical systems. After completing this course, students will: 1. Understand how to specify and reason about operations over complex system structures, 2. Understand relationships between software artifacts at different levels of abstraction; 3. Be able to model and reason about systems with uncertainty and stochastic behaviors; and 4. Understand potential applications of modeling techniques to practical software engineering problems. Prerequisites: Completion of Mini 1: Models of Software Systems. Sections D, PP and G are NOT available for on-campus students. Admission to the class is by approval from the instructor: If you are not a software engineering master's student, send email to garlan@cs.cmu.edu for permission to enroll. The email should briefly describe your background, whether you have taken a course with similar materials as in Mini 1, and why you would like to take the course. The course must be taken for a letter grade (not pass/fail). This is a graduate level course.
Prerequisite: 17-314 Min. grade B

17-331 Information Security, Privacy, and Policy

Fall: 12 units
As layers upon layers of technology mediate increasingly rich business processes and social interactions, issues of information security and privacy are growing more complex too. This course takes a multi-disciplinary perspective of information security and privacy, looking at technologies as well as business, legal, policy and usability issues. The objective is to prepare students to identify and address critical security and privacy issues involved in the design, development and deployment of information systems. Examples used to introduce concepts covered in the class range from enterprise systems to mobile and pervasive computing as well as social networking. Format: Lectures, short student presentations on topics selected together with the instructor, and guest presentations. Target Audience: Primarily intended for motivated undergraduate and masters students with CS background. Also open to PhD students interested in a more practical, multi-disciplinary understanding of information security and privacy.

17-332 Software Project Management

Spring: 6 units
Projects are temporary organizations set up to achieve a one time objective in an agreed time frame. They are characterized by requiring the execution of interrelated, normally non repeating activities, by multidisciplinary groups. Because of its temporary nature and the interrelatedness of its activities, projects require prescriptive planning, budgeting, staffing and risk management. This course will introduce student to fundamental project management techniques and tools such as activity planning, milestone planning, estimation, work breakdown structures, critical paths. The course will also look at hybrid methods such as Milestone Driven Agile Execution and Disciplined Agile Delivery.

17-333 Privacy Policy, Law, and Technology

Fall: 9 units
This course focuses on policy issues related to privacy from the perspectives of governments, organizations, and individuals. We will begin with a historical and philosophical study of privacy and then explore recent public policy issues. We will examine the privacy protections provided by laws and regulations, as well as the way technology can be used to protect privacy. We will emphasize technology-related privacy concerns and mitigation, for example: social networks, smartphones, behavioral advertising (and tools to prevent targeted advertising and tracking), anonymous communication systems, big data, and drones. This is part of a series of courses offered as part of the MSIT-Privacy Engineering masters program. These courses may be taken in any order or simultaneously. Foundations of Privacy (Fall semester) offers more in-depth coverage of technologies and algorithms used to reason about and protect privacy. Engineering Privacy in Software (Spring semester) focuses on the methods and tools needed to design systems for privacy. This course is intended primarily for graduate students and advanced undergraduate students with some technical background. Programming skills are not required. 8-733, 19-608, and 95-818 are 12-unit courses for PhD students. Students enrolled under these course numbers will have extra assignments and will be expected to do a project suitable for publication. 8-533 is a 9-unit course for undergraduate students. Masters students may register for any of the course numbers permitted by their program. This course will include a lot of reading, writing, and class discussion. Students will be able to tailor their assignments to their skills and interests. However, all students will be expected to do some writing and some technical work.

17-334 Usable Privacy and Security

Spring: 9 units
There is growing recognition that technology alone will not provide all of the solutions to security and privacy problems. Human factors play an important role in these areas, and it is important for security and privacy experts to have an understanding of how people will interact with the systems they develop. This course is designed to introduce students to a variety of usability and user interface problems related to privacy and security and to give them experience in designing studies aimed at helping to evaluate usability issues in security and privacy systems. The course is suitable both for students interested in privacy and security who would like to learn more about usability, as well as for students interested in usability who would like to learn more about security and privacy. Much of the course will be taught in a graduate seminar style in which all students will be expected to do a weekly reading assignment and each week different students will prepare a presentation for the class. Students will also work on a group project throughout the semester. The course is open to all graduate students who have technical backgrounds. The 12-unit course numbers (08-734 and 5-836) are for PhD students and masters students. Students enrolled in these course numbers will be expected to play a leadership role in a group project that produces a paper suitable for publication. The 9-unit 500-level course numbers (08-534 and 05-436) are for juniors, seniors, and masters students. Students enrolled in these course numbers will have less demanding project and presentation requirements.

17-335 Software Architectures

Spring: 6 units
Successful design of complex software systems requires the ability to describe, evaluate, and create systems at an architectural level of abstraction. This course introduces architectural design of complex software systems. The course considers commonly-used software system structures, techniques for designing and implementing these structures, models and formal notations for characterizing and reasoning about architectures, tools for generating specific instances of an architecture, and case studies of actual system architectures. It teaches the skills and background students need to evaluate the architectures of existing systems and to design new systems in principled ways using well-founded architectural paradigms. After completing this course, students will be able to: 1. describe an architecture accurately 2. recognize major architectural styles in existing software systems 3. generate architectural alternatives for a problem and choose among them 4. construct a medium-sized software system that satisfies an architectural specification 5. use existing definitions and development tools to expedite such tasks 6. understand the formal definition of a number of architectures and be able to reason about the properties of those architectures 7. use domain knowledge to specialize an architecture for a particular family of applications.

17-336 Applied Distributed Systems

Spring: 6 units
Modern computing systems are frequently hosted on the cloud. That is, they are inherently distributed systems. To appropriately build and deploy these systems developers should know not only about development tools such as container management tools but also the structure of the cloud - in particular how it utilizes virtual machines, containers and networks. They should also understand security mechanisms both in the internet and how to authorize users and maintain credentials securely. Finally, to protect the system once it is placed into production, a developer needs to know how to enable the detection of problems during execution through collection and navigation of logs produced by the system. These are the topics covered by this course.

17-338 Network Analysis: The Hidden Structures behind the Webs We Weave

Fall: 12 units
Previously Course number 17213 Have you wondered how Linux and the subsequent development of open-source software ecosystems could thrive despite weak economic incentives? Why do large-scale complex software systems sometimes fail despite well-developed guardrails and practices? What makes a recommendation system on social media so effective and so toxic at the same time? Why do YouTube mega-influencers with tens of millions of subscribers exist, yet each of us only recognize a handful of them at best? Why do echo chambers form and polarization deepen in social media platforms despite the utopian promise of frictionless connectivity that these platforms initially envisioned? How can you land your dream jobs? How does mass adoption of technological innovations happen (e.g., Python, Bitcoin)? Underlying these seemingly unrelated questions is the powerful influence of social networks, the collection of on- and offline social connections, communications, and collaborations that people form with one another. This course offers an introduction to the study of social networks as a powerful tool for formalizing these wide range of questions, for understanding social dynamics in various settings, and for solving real-world problems arising at the intersection of human social behavior and technological systems. The course first introduces network science concepts and their mathematical operationalization's that give rigorous definitions to fuzzy words we use to describe the social world, such as "status" and "social group". Students will subsequently learn how these network concepts were used to analyze and solve a wide range of puzzling online social phenomena. Finally, the course will introduce statistical models of networks that enable principled investigation of network formation mechanisms.

Course Website: https://bvasiles.github.io/networks/

17-340 Green Computing

Intermittent: 9 units
Note: Previously offered as 08-340. Energy is a key societal resource. However, our energy usage is rising at an alarming rate and therefore it has become critical to manage its consumption more efficiently for long term sustainability. This course introduces students to the exciting area of "Green Computing", and is organizationally divided into two tracks. The first track is "Energy-Efficient Computing", which considers the state of the art techniques for improving the energy efficiency of mobile devices, to laptop and desktop class computers and finally to data centers. We will cover energy efficiency across the hardware/software stack, starting from the individual components like processors and radio interfaces to system level architectures and optimizations. The second track is "Applying Computing towards Sustainability", covering topics that leverage computing to reduce the energy footprint of our society. In particular, we will focus on Smart Buildings and the Smart Grid, covering topics such as sensing, modeling and controlling the energy usage of buildings, new operating systems or software stacks for the smart infrastructure, as well as the privacy and security issues with the new "internet of things". The goal of this course is to help students acquire some of the knowledge and the skills needed to do research in this space of "Green Computing". Although the course is listed within SCS, it should be of interest to students in several departments, including ECE, MechE, CEE, EPP and Architecture.

17-346 DevOps and Continuous Integration

Spring: 6 units
DevOps: Engineering for Deployment and Operations": DevOps is the term given to a modern movement to establish practices that significantly reduce the time to production of committed code. This time involves deployment - the period between the completion of the code by the developers and the placing of the code into normal production and dealing with operations issues. Deployment time can be days, weeks, or even months when using normal development practices. Operational issues such as dealing with incidents and errors introduce other delays. Modern internet companies deploy a system multiple or even dozens of times every day. Achieving this velocity requires coordinated process and design activities together with supporting tooling. This course will cover the deployment process and the associated tooling, it will highlight reasons why release schedules can be slow, and it will introduce the practices that are used to enable high velocity deployments. It will also cover the kinds of problems that are created because of high velocity and how modern internet companies deal with these problems. Please note: This is a required course for MSE-SS students. Students outside of the software engineering department may take this course but students of the MSE programs will have first priority.
Prerequisite: 17-336 Min. grade B

17-350 Information Technology Policy: Evidence, Communication, & Advocacy

Spring: 9 units
In recent decades, developments in Information and Communication Technologies (ICTs) have rapidly moved from research environments to products and services used by billions of people. This rapid rate of change has often resulted in a public which does not understand the technologies shaping their lives and lawmakers who are poorly equipped to make sound policy. It is therefore incumbent upon specialists to communicate how ICTs work to the public and lawmakers so policy making is shaped by evidence and reflects public desires. This course will train students to be effective communicators and advocates in the ICT space. Students taking this course will learn about the broader scope of technology policymaking including formal lawmaking, agency rule-making, strategic litigation, and corporate social responsibility. Current ICT policy topics in privacy, free expression, net neutrality, and competition will be covered. Public communication strategies such as writing op-eds, interviewing with journalists, producing explanatory videos and interactive games will be explored. Finally, students will learn how to perform an expert role in areas such as writing policy briefs and providing testimony. The course is open to advanced undergraduate and graduate students. Graduate students whose research has public policy implications are encouraged to develop projects related to their research. There is no requirement for programming knowledge, but students with experience in developing interactive media and games will be encouraged to utilize such skills. The class will focus heavily on readings, critical evaluation of real ICT advocacy campaigns, and homework will provide hands-on experience with numerous strategies for public engagement. At the end of the semester students will have a portfolio of projects which they may release publicly.

17-355 Program Analysis

Fall and Spring: 12 units
This course covers both foundations and practical aspects of the automated analysis of programs, which is becoming increasingly critical to find software errors and assure program correctness. The theory of abstract interpretation captures the essence of a broad range of program analyses and supports reasoning about their correctness. Building on this foundation, the course will describe program representations, data flow analysis, alias analysis, interprocedural analysis, dynamic analysis, Hoare Logic and verification, program synthesis and repair, model checking, and symbolic execution. Through assignments and projects, students will design and implement practical analysis tools that find bugs and verify properties of software. This course satisfies the Logic and Languages constrained elective category of the Computer Science major, the Theoretical Foundations requirement of the Computer Science master's degree, and the Technical Software Engineering requirement for the Software Engineering minor.
Prerequisites: 15-251 Min. grade C and (17-214 or 15-150 Min. grade C)

Course Website: https://cmu-program-analysis.github.io/

17-356 Software Engineering for Startups

Spring: 12 units
Startup engineering is critical to innovation. The skills required to effectively prototype, launch, and scale products are vital to engineers everywhere, from fledgling companies founded in dorm rooms to local mid-size companies to internal startups from multi-national tech giants. However, developing software in a startup environment poses unique engineering challenges. These challenges include making and justifying foundational architectural and technical decisions despite extreme uncertainty; rapidly prototyping and evaluating new ideas and features, while building minimum viable products; prioritizing engineering effort in severely constrained environments; and communicating effectively both within a small engineering team and with internal and external non-technical stakeholders. This course teaches the skills necessary to engineer successfully in a startup environment, through lectures, group projects, case study discussions, and guest speakers drawn from experienced, practicing startup engineers. This is an engineering-focused course; no entrepreneurship background is required or expected. Students do not need to have a startup idea to participate fully.
Prerequisites: 15-213 or 17-514 or 17-214 or 15-214

17-363 Programming Language Pragmatics

Fall: 12 units
This course provides a broad and pragmatic foundation in the most basic tool of the programmer: programming languages. It starts with the fundamentals of syntax, parsing, and binding, the core structural concepts in programming languages. The course will then cover program semantics and type systems, and students will learn to relate them with a type soundness theorem. Finally, a coverage of intermediate optimization and code generation offers the opportunity to discuss both producing efficient code and reasoning about the correctness of program transformations. Assignments involve a combination of tool-assisted formal reasoning and proofs about programming languages, and implementing these language constructs in a compiler. This course fulfills the Logic and amp; Languages constrained elective of the B.S. in Computer Science. Students with substantial math and programming experience who have not satisfied the specific prerequisites can contact the instructor for permission to enroll.
Prerequisites: 15-150 Min. grade C and (21-228 Min. grade C or 15-251 Min. grade C)

Course Website: http://www.cs.cmu.edu/~aldrich/courses/17-363/

17-396 Language Design and Prototyping

Spring: 12 units
Many programmers think of programming languages as having a fixed, standard set of features and #8212;but in fact, languages are being extended all the time, and new languages are constantly being developed, providing great expressive power. In this course, students will learn about techniques for designing and prototyping programming languages. Design topics include language features, a practical approach to semantics, conceptual design techniques, and examples of both general purpose and domain-specific language designs. Prototyping topics include interpreters, source-to-source translators, languages as libraries, and paper prototyping techniques used for lightweight user evaluations. In course assignments, students will practice design and prototyping techniques, implementing prototype languages in several different styles. The course will end with a project in which students design, implement, and evaluate their own programming language.
Prerequisites: 17-214 or 17-514 or 15-213

Course Website: http://www.cs.cmu.edu/~aldrich/courses/17-396/

17-397 Intro to Qualitative Research: Social Media Apps and Video Content Creation

Spring: 12 units
Short-video apps, such as TikTok, have revealed themselves to be highly accessible and increasingly ubiquitous in regards to online social interaction and are currently the most popular social media among mostly young(er) users. This course focuses on how humans as users interact with and understand social technology and how the use of social media apps is connected to and integrated into our everyday life by asking questions like: What are users' motivations to participate in video creation and sharing on social media? What are their practices, strategies, and routines in creating short-form videos as part of digital online culture? What do they know about socio-technical aspects in using short-video apps and creating short-form video content? How does their understanding of socio-technological aspects influence their use of social media apps? This course is designed to enable students to develop and conduct their own individual research project. For this, students will learn how to design, conduct, and analyze qualitative interviews to research socio-technical, cultural, and political perspectives of usage of and engagement with short-form videos and short-video apps, such as TikTok. The course instructor will closely mentor and supervise students' research projects throughout the semester and will provide expertise and background in qualitative methods and social media research to guide students through the research process.

17-400 Machine Learning and Data Science at Scale

Fall and Spring: 12 units
Datasets are growing, new systems for managing, distributing, and streaming data are being developed, and new architectures for AI applications are emerging. This course will focus on techniques for managing and analyzing large datasets, and on new and emerging architectures for applications in machine learning and data science. Topics include machine learning algorithms and how they must be reformulated to run at scale on petabytes of data, as well as data management and cleaning techniques at scale. In addition to large-scale aspects of data science and machine learning, this course will also cover core concepts of parallel and distributed computing and cloud computing, including hands-on experience with frameworks like Spark, streaming architectures like Flink or Spark Streaming, MLlib, TensorFlow, and more. The course will include programming assignments and a substantial final project requiring students to get hands-on experience with large-scale machine learning pipelines or emerging computing architectures.
Prerequisites: 15-214 or 17-214 or 17-514 or 10-601 or 10-301 or 15-211 or 10-701

Course Website: http://euro.ecom.cmu.edu/program/courses/tcr17-803 (http://euro.ecom.cmu.edu/program/courses/tcr17-803/)

17-401 Software Engineering for AI-Enabled Systems

Fall: 12 units
New Course Need Description

Course Website: https://ckaestne.github.io/seai/

17-402 AI and Emerging Economies

Intermittent: 3 units
The course will cover some of the unique aspects of emerging economies as it relates to AI consumption and responsible AI development. The importance of local data and domain knowledge will be illustrated. Germane to budding technologists, entrepreneurs and policy influencers. Multi-disciplinary.

17-405 Grand Challenges in AI: Past, Present and Future

Intermittent: 3 units
Innovative, bold initiatives that capture the imagination of researchers and system builders are often required to spur a field of science or technology forward. A vision for the future of artificial intelligence was laid out by Turing Award winner and Moza Bint Nasser University Professor at CMU, Raj Reddy in his 1988 Presidential address to the Association for the Advancement of Artificial Intelligence. It is time to provide an accounting of the progress that has been made in the field, over the last three decades, toward the challenge goals. While some tasks such as the world-champion chess machine were accomplished in short order, many others, such as self-replicating systems, require more focus and breakthroughs for completion. A new set of challenges for the current decade is also proposed, spanning the health, wealth, and wisdom spheres. The above - plus commentary from half a dozen AI thought leaders - forms the basis of an article in the 2021 Spring Issue of AI Magazine.

17-413 Software Engineering Practicum

Spring: 12 units
This course is a project-based course in which students conduct a semester-long project for a real client in small teams. This is not a lecture-based course; after the first few weeks the course consists primarily of weekly team meetings with the course instructors, with teams making regular presentations on their software development process. Students will leave the course with a firsthand understanding of the software engineering realities that drive SE practices, will have concrete experience with these practices, and will have engaged in active reflection on this experience. After the course, students will have the teamwork, process, and product skills to be immediately competent in a software engineering organization, and will be able to evaluate the new processes and techniques they will encounter in the workplace.
Prerequisite: 17-313

17-415 Software Engineering Reflection

Fall: 6 units
This course is an opportunity to reflect on a software engineering experience you have had in industry. It is structured as a writers workshop, in which you will work with the instructor and other students to identify and flesh out a software engineering theme that is illustrated by your industry experience. You will prepare a 10-page report on this theme, comparable to a practitioner's report at a conference like ICSE or OOPSLA, and a 30-minute presentation to match. This course fulfills a requirement of the Software Engineering Minor program, but students in other programs may take the course if they meet the prerequisite industry experience and if space is available.

17-416 AI Governance: Identifying & Mitigating Risks in Design & Dev of AI Solutions

Fall and Spring: 6 units
With AI and ML finding their way into an increasingly broad range of products and services, it is important to identify and mitigate the risks associated with the adoption of these technologies. This course reviews the different types of risks associated with AI and discusses methodologies and techniques available to identify and mitigate these risks. The course introduces students to ethical frameworks available to identify and analyze risks. It also examines best practices emerging from both government and industry efforts in this area. This includes looking at new regulations such as the EU AI Act as well as emerging frameworks such as the one developed by NIST. The course also examines frameworks developed by leading companies and how these frameworks combine both technical and non-technical approaches. It further discusses changes that need to be enacted by organizations to adopt more systematic approaches to AI governance. This course combines a mix of technical, policy, and management discussions.

17-422 Building User-Focused Sensing Systems

Fall and Spring: 12 units
These days we are surrounded by sensing and computation. Smart devices, such as smartphones, smartwatches, are packed with sensors. While they are already very useful devices, we have only started to scratch the surface here. The aim of this class will be to introduce the students to building and understanding smart sensing devices. The course will include discussion into contribution of various fields, including human-computer interaction, embedded computing, computer vision, distributed systems, machine learning, signal processing, security, and privacy. We will discuss how these various disciplines are coming together to form an end-to-end system that generates useful and user-actionable data. We will take a hands-on approach towards building and evaluating these systems. The students will gain practical experience in developing sensing systems in different application domains, such as activity recognition, health sensing, gestural interaction, etc. You will learn about embedded systems and understand the advantages and limitations of different platforms. You will learn about sensors and how to interface them with the real world to be able to get useful and actionable data. You will learn how to build a network of sensors that can communicate with each other. You will also learn about storing the sensor data for visualization, analysis and presentation both locally and to the cloud. The course will be a combination of lectures, tutorials, class discussions, and demonstrations. Students will be evaluated based on 5 mini-projects/assignments, class participation, weekly reading summaries, and a final project. All hardware resources will be provided to the students and they will be given an option to take their final prototypes with them for the cost of the hardware components. Students should have reasonable programming experience and an interest in tinkering.

Course Website: https://synergylabs.org/courses/17-722/

17-423 Designing Large-scale Software Systems

Spring: 12 units
Design plays a crucial role in the success of a software product, as decisions made during the design stage have a long-lasting impact on qualities such as reliability, robustness, maintainability, scalability, and security. With the increasing use of AI-based programming tools (such as ChatGPT and Copilot), being able to effectively design large, complex software and reason about systems at scale will become highly sought-out skills in the software industry. This course teaches students how to design complex, large-scale software systems that are reliable, robust, and built to last. It introduces fundamental concepts and techniques for designing software to achieve qualities of a successful product (such as maintainability, scalability, and robustness) and to avoid catastrophic failures. After taking this course, students will be able to (1) systematically generate and explore design alternatives, (2) specify and evaluate design options using appropriate abstractions, and (3) communicate and critique design decisions with other members of large, multi-team organizations. The discussions of these concepts will be driven by case studies of past failures and successes in real-world software systems. The course will be hands-on and involve a semester-long project where the students will work in teams and collaborate with other teams to design, test, and deploy a complex software system. This course is aimed at both undergraduate and graduate students who are interested in the role of a software architect or designer in an organization.

Course Website: https://cmu-swdesign.github.io/

17-428 Machine Learning and Sensing

Fall: 12 units
Machine learning and sensors are at the core of most modern computing devices and technology. From Amazon Echo to Apple Watch to Google Photos to self-driving cars, making sense of the data coming from powerful but noisy sensors is the key challenge. The aim of the course will be to explore this intersection of sensors and machine learning, understand the inner workings on modern computing technologies, and design the future ones. We will cover data collection, signal processing, data processing, data visualization, feature engineering, machine learning tools, and some prototyping technologies. The course will focus on class discussions, hands-on demonstrations, and tutorials. Students will be evaluated on their class participation, multiple mini projects, and a final team project.

17-437 Web Application Development

Fall and Spring: 12 units
This course will introduce concepts in programming web application servers. We will study the fundamental architectural elements of programming web sites that produce content dynamically. The primary technology introduced will be the Django framework for Python, but we will cover related topics as necessary so that students can build significant applications. Such topics include: HTTP, HTML, CSS, Javascript, JSON, Design Patterns, Relational and Non-relational Databases, Object-Relation Mapping tools, Security, Web Services, Cloud Deployment, Internationalization, and Scalability and Performance Issues. Students must be comfortable programming in Python to register for this course. Students must provide their own computer hardware for this course. Please visit the Course URL for more information about the course.
Prerequisites: 18-613 or 15-213 or 18-213 or 14-513 or 17-214 or 15-214 or 17-514 or 15-513

Course Website: https://www.cmu-webapps.org/static/index/syllabus.pdf

17-442 Software Management Theory

Spring: 6 units
This course will look at software development from an organizational perspective and its designed for students who want to understand the relationship between business context, software development processes, knowledge creation, culture and organizational structure with the purpose of becoming change agents or manage the software development function at the department, business unit level or above. The course will also highlight the need to follow good work principles in order to avoid ethical failures as evidenced by recent affairs

17-443 Quality Management

Spring: 6 units
Managing software quality is a critical part of all software projects. Software engineers must consider quality during every phase of a project from inception to delivery and beyond. This class will introduce students to the managerial challenges of developing high quality software systems. The key learning objectives of this course include: 1. Define a quality management process in the context of a software project. 2. Understand the costs associated with achieving quality goals and not achieving them 3. Understand the tradeoffs required to implement quality assurance techniques. 4. Gain experience using collected quality metrics to inform project-level decisions.
Prerequisite: 17-323 Min. grade B

17-445 Machine Learning in Production

Fall and Spring: 12 units
The course takes a software engineering perspective on building software systems with a significant machine learning or AI component. It discusses how to take an idea and a model developed by a data scientist (e.g., scripts and Jupyter notebook) and deploy it as part of scalable and maintainable system (e.g., mobile apps, web applications, IoT devices). Rather than focusing on modeling and learning itself, this course assumes a working relationship with a data scientist and focuses on issues of design, implementation, operation, and assurance and how those interact with the data scientist's modeling. This course is aimed at software engineers who want to understand the specific challenges of working with AI components and at data scientists who want to understand the challenges of getting a prototype model into production; it facilitates communication and collaboration between both roles.

Course Website: https://ckaestne.github.io/seai/

17-446 DevOps and Continuous Integration

Spring: 6 units
TBD
Prerequisite: 17-336 Min. grade B

17-450 Crafting Software

Fall and Spring: 12 units
Do you use programming to solve problems in your field of study? Do you know enough to be dangerous, but wish you could be proud of your code? This course aims to provide students with sufficient knowledge and skills to use programming as part of their work. In this class, you will learn how to identify and find problems in your code. You will learn to read, parse, organize, and transform data. We will teach you to write code collaboratively and refine your programs so others can use them.The course will be a mixture of lecture and guided exercise with a recitation focused on hands on instruction. In this course, students are expected to have been exposed to some basic programming concepts, such as variables, if-statements, loops, and arrays. However, students are not expected to have extensive programming experience. This course is not appropriate for students that have completed more than two courses involving programming. We expect students in this class to have diverse backgrounds and experience. Some students will be self-taught, while others will have taken a programming course such as 02-201, 15-110, 95-898, or the library's Software Carpentry workshop. If you have questions about your background and the fit for this class, please don't hesitate to reach out to the instructors.

17-470 Virtual Machines and Managed Runtimes

Fall: 12 units
Traditional compiler and programming language courses focus on language implementations that generate code statically (offline) for a target machine. Yet in today's landscape, many programming languages run on virtual machines where either a virtual instruction set architecture (bytecode) or the source code of the program is translated (and optimized) dynamically for an underlying machine. Such languages come with additional challenges beyond traditional compilation as taught in courses, including efficient representation of high-level language constructs and automatic memory management in the form of garbage collection. Together, the components of the virtual machine and services form what is known as a managed runtime system. This course focuses on implementation techniques for managed runtime systems. Students will learn the basics of virtual machine implementation and build working prototypes to run actual programs. Prior knowledge of compilers and some familiarity with programming language implementation is required.
Prerequisites: 15-611 or 15-411

17-480 API Design and Implementation

Fall and Spring: 12 units
This class focuses on the design of programming interfaces, the APIs, within larger real-world software and ecosystems. We discuss the history and importance of APIs, and the principles behind designing good APIs. This includes study of specific examples of APIs, both good and bad, for inspiration and precaution. Students gain experience with the major steps of API design: gathering requirements, documenting, testing, implementing, refining, evolving, and reimplementing APIs. The principles taught are largely language-independent, though most examples are in Java or C. Students may be able to do assignments in other languages, within reason.
Prerequisites: 17-214 or 15-214 or 15-213

17-514 Principles of Software Construction: Objects, Design, and Concurrency

Fall and Spring: 12 units
Software engineers today are less likely to design data structures and algorithms from scratch and more likely to build systems from library and framework components. In this course, students engage with concepts related to the construction of software systems at scale, building on their understanding of the basic building blocks of data structures, algorithms, and program and computer structures. The course covers technical topics in four areas: (1) concepts of design for complex systems, (2) object-oriented programming, (3) static and dynamic analysis for programs, and (4) concurrency. At the conclusion of this course, students will have substantial experience building medium-sized software systems in Java or JavaScript.
Prerequisites: (15-122 Min. grade C or 15-121 Min. grade C) and (21-128 Min. grade C or 21-127 Min. grade C or 15-151 Min. grade C)

Course Website: https://www.cs.cmu.edu/~ckaestne/17214/f2021/

17-536 Pervasive and Ubiquitous Computing

Intermittent: 12 units
Note: Previously offered as 08530. The aim of the class will be to explore the area of Ubiquitous Computing (ubicomp) and allow students to work on a variety of small technology projects. Students will be exposed to the basics of building ubicomp systems, emerging new research topics, and advanced prototyping techniques. This course will focus more on class discussions and hands on demonstrations, while formal lectures will be conducted only as needed. Students will be evaluated on their class participation, reading summaries, and mini projects.

17-537 Artificial Intelligence Methods for Social Good

Spring: 9 units
Optimization: mathematical programming, robust optimization, influence maximization Game Theory and Mechanism Design: security games, human behavior modeling, auction and market equilibrium, citizen science Machine Learning: classification, clustering, probabilistic graphical models, deep learning Sequential Decision Making: Markov Decision Processes (MDPs), partially observable MDPs, online planning, reinforcement learning In addition to providing a deep understanding of these methods, the course will introduce which societal challenges they can tackle and how, in the areas of (i) healthcare, (ii) social welfare, (iii) security and privacy, (iv) environmental sustainability. The course will also cover special topics such as AI and Ethics and AI and Humans. The course content is designed to not have too much overlap with other AI courses offered at CMU. Although the course is listed within SCS, it should be of interest to students in several other departments, including ECE, EPP and SDS. The students in this 9-unit course are expected to have taken at least three mathematics courses covering linear algebra, calculus, and probability. The students will work in groups on a systematic literature review or a project exploring the possibility of applying existing AI tools to a societal problem, with a survey paper or technical report and presentation delivered at the end of the semester.

17-562 Law of Computer Technology

Fall: 9 units
A survey of how legislatures and courts cope with rapidly advancing computer technologies and how scientific information is presented to, and evaluated by, civil authorities. The course is also an introduction to the legal process generally and the interaction between the legal system and technology organizations. Topics include: patents, copyrights in a networked world, law of the Internet, free speech, data security, technology regulation, international law, and trans-border crime. Open to juniors, seniors and graduate students in any school. Open to sophomores by permission of the instructor. Prerequisites: none.

17-599 Advanced Topics in Machine Learning and Game Theory

Fall: 12 units
This course is designed to be a graduate-level course covering the topics at the intersection of machine learning and game theory. Recent years have witnessed significant advances in machine learning and their successes in detection, prediction, and decision-making problems. However, in many application domains, ranging from auction and ads bidding, to entertainment games such as Go and Poker, to autonomous driving and traffic routing, to the intelligent warehouse, to home assistants and the Internet of Things, there is more than one agent interacting with each other. Game theory provides a framework for analyzing the strategic interaction between multiple agents and can complement machine learning when dealing with challenges in these domains. Therefore, in the course, we will introduce how to integrate machine learning and game theory to tackle challenges in multi-agent systems. The course will multiple topics as listed below

Course Website: https://feifang.info/advanced-topics-in-machine-learning-and-game-theory-fall-2021/

17-612 Business and Marketing Strategy

Fall and Spring: 6 units
This course prepares technically minded students to understand and use essential business concepts in their careers. With this competency, students will be able to make use of, contribute to, and influence the business, product and marketing decisions that affect engineering and technology decisions, quality, and performance. Students will be better equipped to make business arguments for supporting their product, technology and engineering ideas in their future, too. This 6-unit course emphasizes learning-by-doing to achieve the learning objectives. The teaching and learning approach uses a situation that many students will encounter in their early careers: to conceive, plan and propose a new product idea. Each student works on a course-long project to add a new technology product idea for an existing company's product line. They'll make product, technology, pricing, marketing, and sales decisions to achieve success and support of the company's strategy and business decisions. Their work will culminate in building a compelling business case, with financial projections, to persuade the company executives to invest in the product idea.

Course Website: https://mse.s3d.cmu.edu/

17-619 Introduction to Real-Time Software and Systems

Intermittent: 12 units
Introduction to Real-Time Software and Systems presents an overview of time as it relates engineering complex systems. Any system that responds at the pace of relevant events has real-time constraints whether the timescale is short, like the flight controls for an aircraft, or longer, like the flight reservation system for an airline. Fundamental concepts, terminology, and issues of real-time systems are introduced in this course. The focus is on software solutions to real-time problems-solutions that must be both correct and timely. Software development is examined with emphasis on real-time issues during each phase of the software lifecycle. Real-time requirements analysis, architecting real-time systems, designing and modeling system timing, and implementation and testing strategies are studied. Modeling techniques using UML 2.0 are applied. Particular emphasis is placed on real-time scheduling to achieve desired timing, reliability, and robustness. Languages and operating systems for real-time computing, and real-time problems in concurrent and distributed systems are explored. This course provides a comprehensive view of real-time systems with theory, techniques and methods for the practitioner. After successfully completing this course, the student will be able to identify constraints and understand real-time issues in system development, and propose approaches to typical real-time problems. The aim of this course is to motivate and prepare students to pursue more in-depth study of specific problems in real-time computing and systems development. REQUIREMENT: Proficiency with a high-level programming language such as C or Ada and basic concepts of computing systems. Familiarity with software engineering concepts and system development lifecycle.

17-621 Computer Simulation of Complex Socio-Technical Systems

Intermittent: 12 units
How likely is an intervention like social distancing to save lives? Will a law legislating sanctions against social media platforms that spread disinformation stop the spread? We live and work in complex adaptive and evolving socio-technical systems where questions such as these arise constantly. Questions such as these are often only addressable through computational modeling, i.e., through simulation. Simulation models are a critical method for understanding how to adaptation and learning will change the status-quo. Computational modeling can be used to help analyze, reason about, predict the behavior of, and possibly control complex human systems of "networked" agents. Using simulation it is possible to advance theory, test policies before enacting them, and think through non-linear social effects.

Course Website: http://www.casos.cs.cmu.edu/courses/

17-624 Advanced Formal Methods

Fall: 6 units
This course builds on the introductory Models class to cover more advanced techniques for modeling and reasoning about complex software systems. Concepts introduced in this course include abstraction and refinement, declarative specifications, advanced temporal logics, and probabilistic modeling. The course will also explore applications of modeling and automated reasoning techniques in various domains, such as security, distributed computing, and cyber-physical systems. After completing this course, students will: 1. Understand how to specify and reason about operations over complex system structures, 2. Understand relationships between software artifacts at different levels of abstraction; 3. Be able to model and reason about systems with uncertainty and stochastic behaviors; and 4. Understand potential applications of modeling techniques to practical software engineering problems. Prerequisites: Completion of Mini 1: Models of Software Systems. Sections D, PP and G are NOT available for on-campus students. Admission to the class is by approval from the instructor: If you are not a software engineering master's student, send email to garlan@cs.cmu.edu for permission to enroll. The email should briefly describe your background, whether you have taken a course with similar materials as in Mini 1, and why you would like to take the course. The course must be taken for a letter grade (not pass/fail). This is a graduate level course.
Prerequisite: 17-614 Min. grade B

17-626 Requirements for Information Systems

Fall: 6 units
Software engineering requires understanding the problem, before identifying solutions. In this course, students study ways to elicit and analyze problem statements using scenarios, use cases and mockups.

17-627 Requirements for Embedded Systems

Fall: 6 units
Software engineering requires understanding the problem, before identifying solutions. In this course, students study ways to elicit and analyze problem statements for real-time systems along multiple dimensions, including concurrency, dependability and safety.
Prerequisite: 17-614 Min. grade B

17-634 Applied Machine Learning

Spring: 6 units
Autonomous and intelligent systems increasingly rely on automated decision making based on statistical models used for classification or prediction. The practical application of machine learning requires understanding the underlying theoretical assumptions behind a wide variety of statistical models, how to analyze the performance of such models, and how to integrate models into data processing pipelines. This course introduces students to supervised and unsupervised machine learning in the context of software engineering, including the analysis of natural language in bug reports and mobile app reviews. Techniques covered include latent Dirichlet allocation, TF/IDF, naive Bayes, linear regression, decision trees, and random forests.

17-640 IoT, Big Data, and ML: A Hands-on Approach

Intermittent: 12 units
This course is designed to teach IoT concepts, big data, and machine learning techniques using a hands-on approach. An IoT system simulating an order fulfillment process is central to the hands-on learning of the concepts and techniques. Students will work in 4-5 person teams to enable the system and implement the requirements. In doing so, they will incorporate sound design principles of software engineering acquired in lectures. Students will capture the data generated during the execution of the system as it fulfills orders that are received from a front-end system developed by the students. Students will be expected to prepare, process, and model the data for statistical analysis applying techniques taught in class. They will then visualize, analyze and interpret the results, and implement improvements to obtain a 360-degree experience of a business application using the automated system. This course will provide insight into the ways in which business enterprises think about leveraging technology and software in the management of their production operations. The course prepares students for professional opportunities requiring such skills allowing them to identify use cases that facilitate innovation and promote competitiveness.

17-644 Applied Deep Learning

Spring: 6 units
Deep neural networks have made in-roads in virtually every industry, propelled by exponential increases in compute power and fundamental progress in modeling. Knowledge of these models is fast becoming a key asset for software engineers, as current systems are quickly starting to include many neural components, and the practice of software engineering itself is starting to benefit from neural program assistance (incl. automated bug finding, translation between programming languages). This course equips the next generation of software engineers with knowledge of neural models, the software engineering challenges involved in using these, and hands-on experience with their applications. It teaches both a rich vocabulary of general, essential concepts (including architectures), and recent work on applications of these models, aimed primarily at applications for and in software engineering itself. The course includes a group project aimed at constructing a neural solution for an existing application that will be used to teach the various stages (and their pitfalls) of building and deploying deep learners.

17-651 Models of Software Systems

Fall: 12 units
Scientific foundations for software engineering depend on the use of precise, abstract models for describing and reasoning about properties of software systems. This course considers a variety of standard models for representing sequential and concurrent systems, such as state machines, algebras, and traces. It shows how different logics can be used to specify properties of systems, such as functional correctness, deadlock freedom, and internal consistency. Concepts such as compositionality, abstraction, invariants, non-determinism, and inductive definitions are recurrent themes throughout the course. After completing this course, students will: 1. Understand the strengths and weaknesses of certain models and logics including state machines, algebraic and process models, and temporal logic; 2. Be able to select and describe appropriate abstract formal models for certain classes of systems, describe abstraction relations between different levels of description, and reason about the correctness of refinements; 3. Be able to prove elementary properties about systems described by the models introduced in the course; and 4. Understand some of the strengths and weakness of formal automated reasoning tools. Prerequisites: Undergraduate discrete math including first-order logic, sets, functions, relations, and simple proof techniques such as induction. Sections D, PP and G are NOT available for on-campus students. Admission to the class is by approval from the instructor: If you are not MSE/MSIT-SE/MITS, send email to garlan@cs.cmu.edu for permission to enroll. The email should briefly describe your background, whether you have taken an undergraduate discrete math course, and why you would like to take the course. The course must be taken for a letter grade (not pass/fail). This is a graduate level course.

17-654 Analysis of Software Artifacts

Spring: 12 units
Analysis is the systematic examination of an artifact to determine its properties. This course will focus on analysis of software artifacts and #8212;primarily code, but also including analysis of designs, architectures, and test suites. We will focus on functional properties, but also cover non-functional properties like performance and security. In order to illustrate core analysis concepts in some depth, the course will center on static program analysis; however, the course will also include a breadth of techniques such as testing, model checking, theorem proving, dynamic analysis, and type systems. The course will balance theoretical discussions with lab exercises in which students will apply the ideas they are learning to real artifacts. After completing this course, students will: * know what kinds of analyses are available and how to use them * understand their scope and power,when they can be applied and what conclusions can be drawn from their results * have a grasp of fundamental notions sufficient to evaluate new kinds of analysis when they are developed * have some experience selecting and writing analyses for a real piece of software, applying them and interpreting the results Ph.D. students taking the 17-754 version of the course will gain a broad overview of the analysis research literature and in-depth knowledge of a particular sub-area through a course project. Requirement: A recent discrete math course and programming experience. Strongly Recommended: Models of SW Development course (17-651) before taking this course. This course is for letter grade only (no pass/fail grades). This is a graduate course. Only undergrad SE minors may take this course with the instructor's permission. Please note: Students outside of the software engineering department may take this course but students of the MSE programs will have first priority.

17-663 Programming Language Pragmatics

Fall: 12 units
This course provides a broad and pragmatic foundation in the most basic tool of the programmer: programming languages. It starts with the fundamentals of syntax, parsing, and binding, the core structural concepts in programming languages. The course will then cover program semantics and type systems, and students will learn to relate them with a type soundness theorem. Finally, a coverage of intermediate optimization and code generation offers the opportunity to discuss both producing efficient code and reasoning about the correctness of program transformations. Assignments involve a combination of tool-assisted formal reasoning and proofs about programming languages, and implementing these language constructs in a compiler. This course fulfills the Logic and amp; Languages constrained elective of the B.S. in Computer Science. Students with substantial math and programming experience who have not satisfied the specific prerequisites can contact the instructor for permission to enroll.
Prerequisites: 15-251 Min. grade C and (21-228 Min. grade C or 15-150 Min. grade C)

Course Website: http://www.cs.cmu.edu/~aldrich/courses/17-363/

17-670 Virtual Machines and Managed Runtimes

Fall: 12 units
Traditional compiler and programming language courses focus on language implementations that generate code statically (offline) for a target machine. Yet in today's landscape, many programming languages run on virtual machines where either a virtual instruction set architecture (bytecode) or the source code of the program is translated (and optimized) dynamically for an underlying machine. Such languages come with additional challenges beyond traditional compilation as taught in courses, including efficient representation of high-level language constructs and automatic memory management in the form of garbage collection. Together, the components of the virtual machine and services form what is known as a managed runtime system. This course focuses on implementation techniques for managed runtime systems. Students will learn the basics of virtual machine implementation and build working prototypes to run actual programs. Prior knowledge of compilers and some familiarity with programming language implementation is required.
Prerequisites: 15-411 or 15-611

17-685 Dynamic Network Analysis

Spring: 12 units
Who knows who? Who knows what? Who is influential? What is the social network, the knowledge network, the activity network? How do ideas, products and amp; diseases propagate through groups and impact these networks? Does social media change the way these networks operate? Questions such as these and amp; millions of others require a network perspective and an understanding of how ties among people, ideas, things, and amp; locations connect, constrain and amp; enable activity. In the past decade there has been an explosion of interest in network science moving from the work on social networks and graph theory to statistical and computer simulation models. Network analysis, like statistics, now plays an role in most empirical fields. Network science is a broad and multi-disciplinary field. In this class, students will gain an appreciation of the history of the field, the difference between social networks and social media, the difference graph-based metrics for network analysis and graphical models, the use of traditional and high dimensional network models, and the advances in this field. Applications and issues discussed will include: social media analytics, semantic networks, task networks, organizational design and teams, machine learning and network analysis, generative models, terrorism and crime, health, and fake news. Methods for network data collection, analysis, visualization, and interpretation are covered. Students produce original research in which network data is analyzed using the methods covered in the class

Course Website: http://www.casos.cs.cmu.edu/courses/

17-691 Machine Learning in Practice

Spring: 6 units
As Machine Learning and Artificial Intelligence methods have become common place in both academic and industry environments the majority of resources have focused on methods and techniques for applications. However, there are many considerations that must be addressed when deploying such techniques into practice (or production). The purpose of this course is to cover topics relevant to building a machine learning systems deployed into operations. Such systems have technical requirements including data management, model development, and deployment. However, business/organizational impacts must also be considered. Machine learning systems can be expensive to produce and operate. Students will learn about trade-offs in design, implementation, and expected value. After completing this course, students will: 1. Have the ability to deploy produces with machine learning and AI components; 2. Understand how to implement data pipelines and data engineering systems; 3. Calculate the approximate value provided by a machine learning system to an organization; 4. Understand how to continually assess the value and quality of a deployed machine learning system. Prerequisites: understanding of basic machine learning concepts (i.e. supervised/unsupervised learning). This is a graduate level course.
Prerequisite: 17-634 Min. grade B

17-692 Product Management Essentials I

Fall and Spring: 6 units
This course prepares students to understand and use the essential concepts and practices of product management and innovation. These concepts are used in the critical, early stages of every new product or service idea. Students will acquire the customer-centric knowledge and skills to describe a well-defined, worthwhile customer problem solve; a focused target market of potential customers; specify an innovative and differentiated product solution concept; and design, price and quantify a value proposition that is compelling to customers to buy and use the product. This 6-unit course emphasizes learning-by-doing to achieve the learning objectives. Students work on a hands-on, course-long project focused on a problem space selected by the student and approved by the instructor for course fit.

Course Website: https://mse.s3d.cmu.edu/applicants/course-offerings.html

17-702 Current Topics in Privacy Seminar

Fall and Spring: 3 units
In this seminar course students will discuss recent papers and current public policy issues related to privacy. Privacy professionals from industry, government, and non-profits will deliver several guest lectures each semester.

17-712 Fantastic Bugs and How to Find Them

Fall: 12 units
This advanced course studies the nature of software bugs and security vulnerabilities arising in complex application domains and surveys specialized program analysis + automated testing techniques for identifying such issues proactively. The course will take a tour of various domains such as mobile systems, databases, web browsers, distributed and networked systems, autonomous vehicles, and smart contracts. For each domain, the class will review case studies of high-impact software bugs that have manifested in production and will then discuss state-of-the-art research techniques that aim to uncover such bugs automatically. Apart from the literature review, students will engage significantly with software system design and engineering via hands-on assignments and a semester-long project involving real-world applications and analysis tools for one or more domains. Students completing this course will be able to (a) identify practical challenges of applying well-known program analysis and testing techniques to complex application domains, (b) formulate and leverage domain-specific assumptions for making analysis techniques tractable in a specialized setting, and (c) build practical tools for improving software quality in large-scale systems. The course assumes that students have some background in reasoning about software quality, system security, and/or working with program representations. The course builds upon mathematical principles introduced in foundational classes on program analysis, verification, or compiler design, as well as system design principles encountered in introductory security or software engineering courses. Please check the course website for classes that qualify as sufficient pre-requisites, or contact the instructor to discuss your background.

Course Website: https://cmu-fantastic-bugs.github.io/

17-731 Foundations of Privacy

Fall: 12 units
Privacy is a significant concern in modern society. Individuals share personal information with many different organizations - healthcare, financial and educational institutions, the census bureau, Web services providers and online social networks - often in electronic form. Privacy violations occur when such personal information is inappropriately collected, shared or used. We will study privacy in a few settings where rigorous definitions and enforcement mechanisms are being developed - statistical disclosure limitation (as may be used by the census bureau in releasing statistics), semantics and logical specification of privacy policies that constrain information flow and use (e.g., by privacy regulations such as the HIPAA Privacy Rule and the Gramm-Leach-Bliley Act), principled audit and accountability mechanisms for enforcing privacy policies, anonymous communication protocols - and other settings in which privacy concerns have prompted much research, such as in social networks, location privacy and Web privacy (in particular, online tracking and amp; targeted advertising).

17-733 Privacy Policy, Law, and Technology

Fall: 12 units
NOTE: Previously offered as 08-733. This course focuses on policy issues related to privacy from the perspectives of governments, organizations, and individuals. We will begin with a historical and philosophical study of privacy and then explore recent public policy issues. We will examine the privacy protections provided by laws and regulations, as well as the way technology can be used to protect privacy. We will emphasize technology-related privacy concerns and mitigation, for example: social networks, smartphones, behavioral advertising (and tools to prevent targeted advertising and tracking), anonymous communication systems, big data, and drones. This is part of a series of courses offered as part of the MSIT-Privacy Engineering masters program. These courses may be taken in any order or simultaneously. Foundations of Privacy (Fall semester) offers more in-depth coverage of technologies and algorithms used to reason about and protect privacy. Engineering Privacy in Software (Spring semester) focuses on the methods and tools needed to design systems for privacy. This course is intended primarily for graduate students and advanced undergraduate students with some technical background. Programming skills are not required. 8-733, 19-608, and 95-818 are 12-unit courses for PhD students. Students enrolled under these course numbers will have extra assignments and will be expected to do a project suitable for publication. 8-533 is a 9-unit course for undergraduate students. Masters students may register for any of the course numbers permitted by their program. This course will include a lot of reading, writing, and class discussion. Students will be able to tailor their assignments to their skills and interests. However, all students will be expected to do some writing and some technical work.

17-735 Engineering Privacy in Software

Spring: 12 units
Privacy harms that involve personal data can often be traced back to software design failures, which can be prevented through sound engineering practices. In this course, students will learn how to identify privacy threats due to surveillance activities that enhance modern information systems, including location tracking, behavioral profiling, recommender systems, and social networking. Students will learn to analyze systems to identify the core operating principles and technical means that introduce privacy threats, and they will learn to evaluate and mitigate privacy risks to individuals by investigating system design alternatives. Strategies to mitigating privacy risk will be based on emerging standards and reliable privacy preference data. Students will have the opportunity to study web-, mobile- and cyber-physical systems across a range of domains, including advertising, healthcare, law enforcement and social networking. In addition, students will know how, and when, to interface with relevant stakeholders, including legal, marketing and other developers in order to align software design with privacy policy and law.

17-756 Computational Social Science Research Design and Data Analytics

Spring: 12 units
This course surveys how digital trace data of human activity online, combined with careful research design and data analytics, have led to surprising discoveries and development of novel theoretical explanations in the field of computational social science (CSS). The course has three aims. (a) It is intended to stimulate new ways of formulating research questions on pressing/emerging societal issues of interest (e.g., political polarization, gender representation in open-source software development, decentralized governance based on blockchain technology) given the possibilities afforded by a wide array of digital trace data (e.g., social media, open-source software collaboration, cryptocurrency transactions, satellite imagery). This course will (b) discuss exemplary works in CSS that made novel discoveries or made theoretical and/or methodological breakthroughs and (c) cover practical considerations that commonly arise in a CSS research project cycle. These issues may include, but are not limited to, data collection (sampling methods and bias), repurposing existing datasets that were collected in a different research context, constructing metrics based on theoretical insights, analytic approaches adequate for a given research question (statistical modeling, network analysis, online experiments, simulation-based theory development), big data processing and analytic tools (distributed data processing frameworks, visualization), ethical considerations, and data sharing. In the end, this course will help participants develop "good taste" for theoretically insightful, methodologically creative, and well thought out research, while learning to identify potential pitfalls that could arise in their own research.

17-801 Dynamic Network Analysis

Spring: 12 units
Who knows who? Who knows what? Who is influential? What is the social network, the knowledge network, the activity network? How do ideas, products and amp; diseases propagate through groups and impact these networks? Does social media change the way these networks operate? Questions such as these and amp; millions of others require a network perspective and an understanding of how ties among people, ideas, things, and amp; locations connect, constrain and amp; enable activity. In the past decade there has been an explosion of interest in network science moving from the work on social networks and graph theory to statistical and computer simulation models. Network analysis, like statistics, now plays an role in most empirical fields. Network science is a broad and multi-disciplinary field. In this class, students will gain an appreciation of the history of the field, the difference between social networks and social media, the difference graph-based metrics for network analysis and graphical models, the use of traditional and high dimensional network models, and the advances in this field. Applications and issues discussed will include: social media analytics, semantic networks, task networks, organizational design and teams, machine learning and network analysis, generative models, terrorism and crime, health, and fake news. Methods for network data collection, analysis, visualization, and interpretation are covered. Students produce original research in which network data is analyzed using the methods covered in the class.

Course Website: http://www.casos.cs.cmu.edu/courses/

17-821 Computer Simulation of Complex Socio-Technical Systems

Spring: 12 units
How likely is an intervention like social distancing to save lives? Will a law legislating sanctions against social media platforms that spread disinformation stop the spread? We live and work in complex adaptive and evolving socio-technical systems where questions such as these arise constantly. Questions such as these are often only addressable through computational modeling, i.e., through simulation. Simulation models are a critical method for understanding how to adaptation and learning will change the status-quo. Computational modeling can be used to help analyze, reason about, predict the behavior of, and possibly control complex human systems of "networked" agents. Using simulation it is possible to advance theory, test policies before enacting them, and think through non-linear social effects.

Course Website: http://www.casos.cs.cmu.edu/courses/

17-880 Algorithms for Private Data Analysis

Spring: 12 units
We study the following question in this course: How do we perform useful analysis on a data set that contains sensitive information about individuals without compromising the privacy of those individuals? To study this question, we will introduce differential privacy, a framework of designing data analysis algorithms with strong, meaningful, and mathematically provable privacy guarantees. We will survey a set of algorithmic tools that allow us to privately perform a wide range of statistical analyses. Of course, privacy does not come for free, and we will also study some of the fundamental limitations imposed by the requirement of differential privacy. Through the discussion of these results, we will also demonstrate some of the most novel and surprising connections between differential privacy and other areas of theoretical computer science, including machine learning theory, cryptography, convex geometry, and game theory.

Language Technologies Institute Courses

11-291 Applied Computational Intelligence Lab

Intermittent: 9 units
What would an "intelligent" picture on the wall do? What if it could see and hear you? What should it say if it could talk? What if your pantry, wardrobe or medicine cabinet could sense, think and act? What should they do and say? What should your cell phone be saying to you? These are not whimsical or theoretical questions...they inevitably arise as ordinary everyday objects around us acquire the ability to sense changes in their environment, think about their implications, and act in pursuit of their goals. These objects are connected to the web and become conduits for services, erasing the distinction between products and services. The ability to invent and build smart products/services is becoming a key skill in the new technology-driven services economy. The focus of the course will be on building "ordinary" objects that can sense, think and act in the real world and on exploring the implications of these capabilities. Students will select their own project and by the end of the semester will create a working prototype that will be exhibited in a public place. Prizes will be offered for the most creative projects. In the course of their projects, students will learn how to use state-of-the-art tools for: Object detection using video cameras, microphones and other sensors Movement and gesture detection Speech recognition and generation Reasoning and planning: While the course organizers have many ideas for specific projects, students will be encouraged to design their own projects. Students are expected to work in small groups on their own time and receive faculty advice as needed. There will be weekly meetings of the whole class.
Prerequisites: 21-127 Min. grade C and 15-122 Min. grade C

11-324 Human Language for Artificial Intelligence

Fall: 12 units
An enduring aspect of the quest to build intelligent machines is the challenge of human language. This course introduces students with a background in computer science and a research interest in artificial intelligence fields to the structure of natural language, from sound to society. It covers phonetics (the physical aspects of speech), phonology (the sound-structure of language), morphology (the structure of words), morphosyntax (the use of word and phrase structure to encode meaning), syntactic formalisms (using finite sets of production rules to characterize infinite configurations of structure), discourse analysis and pragmatics (language in discourse and communicative context), and sociolinguistics (language in social context and social meaning). Evaluation is based on seven homework assignments, a midterm examination, and a final examination.

11-344 Machine Learning in Practice

Fall and Spring: 12 units
Machine Learning is concerned with computer programs that enable the behavior of a computer to be learned from examples or experience rather than dictated through rules written by hand. It has practical value in many application areas of computer science such as on-line communities and digital libraries. This class is meant to teach the practical side of machine learning for applications, such as mining newsgroup data or building adaptive user interfaces. The emphasis will be on learning the process of applying machine learning effectively to a variety of problems rather than emphasizing an understanding of the theory behind what makes machine learning work. This course does not assume any prior exposure to machine learning theory or practice. In the first 2/3 of the course, we will cover a wide range of learning algorithms that can be applied to a variety of problems. In particular, we will cover topics such as decision trees, rule based classification, support vector machines, Bayesian networks, and clustering. In the final third of the class, we will go into more depth on one application area, namely the application of machine learning to problems involving text processing, such as information retrieval or text categorization.

11-345 Undergrad Independent Study

All Semesters
No course description provided.

11-364 An Introduction to Knowledge-Based Deep Learning and Socratic Coaches

Spring: 12 units
The subject of this course will be deep learning, one of the most dynamic and exciting emerging areas of computer science. Deep learning deals with and is conquering the problems resulting from the enormous quantity of data that now surrounds us. Furthermore, the course will explore knowledge-based deep learning, a new methodology invented by the instructor that offers many potential advantages over conventional deep learning. This is a learn-by-doing, team-project based course, which will be divided into four phases. In phase one, each student will read and present a number of papers describing state-of-the-art deep learning systems and successful applications. In phase two, each team will implement the system described in one of the papers. In phase three, each team will scale that implementation to one of the large benchmark datasets. In phase four, each team will do a special research project implementing a knowledge-based deep learning system based on pending patent applications of Professor Baker. As a potential follow-on for successful projects, students may participate in a summer course on entrepreneurial applications of deep learning or work as interns in a bootstrap startup based on the knowledge-based deep learning projects. Prerequisite: Strong quantitative aptitude, programming skill, ability to quickly absorb new ideas, teamwork skills.

11-390 LTI Minor Project - Juniors

All Semesters: 12 units
No course description provided.

11-411 Natural Language Processing

Intermittent: 12 units
This course is about a variety of ways to represent human languages (like English and Chinese) as computational systems, and how to exploit those representations to write programs that do neat stuff with text and speech data, like translation, summarization, extracting information, question answering, natural interfaces to databases, and conversational agents. This field is called Natural Language Processing or Computational Linguistics, and it is extremely multidisciplinary. This course will therefore include some ideas central to Machine Learning and to Linguistics. We'll cover computational treatments of words, sounds, sentences, meanings, and conversations. We'll see how probabilities and real-world text data can help. We'll see how different levels interact in state-of-the-art approaches to applications like translation and information extraction. From a software engineering perspective, there will be an emphasis on rapid prototyping, a useful skill in many other areas of Computer Science.
Prerequisite: 15-122

11-422 Grammar Formalisims

Spring: 12 units
TBA

11-423 ConLanging: Lrng. Ling. & Lang Tech via Constru Artif. Lang.

Spring: 12 units
Students will work individually or in small groups to create artificial human(oid) languages for fictional human cultures or SciFi worlds. Students will implement language technologies for their languages. In the course of creating the languages, students will learn about the building blocks of human language such as phones, phonemes, morphemes, and morpho-syntactic constructions including their semantics and pragmatics. Class instruction will focus specifically on variation among human languages so that the students can make conlangs that are not just naively English-like. We will also touch on philosophical issues in philosophy of language and on real-world socio-political issues related to language policy. Students will be required to use at least one of the following technologies: language documentation tools that are used for field linguistics and corpus annotation, automatic speech recognition, speech synthesis, morphological analysis, parsing, or machine translation. Learning Objectives: 1. The building blocks (phonemes, morphemes, etc.) of language, how languages are built from them, and how they interact 2. Metalinguistic awareness and knowledge about variation in human language 3. Language, thought, and culture: how does language reflect thought and culture, and vice versa. Why wouldn't Elvish be a good language for Klingons? 4. Language policy in the real world: For students who want to manipulate real languages. 5. Historical linguistics and language change: for students who want to manipulate real languages or make families of related conlangs for fictional worlds. 6. Practical experience with a language technology. http://tts.speech.cs.cmu.edu/11-823/
Course Website: http://tts.speech.cs.cmu.edu/11-823 (http://tts.speech.cs.cmu.edu/11-823/)

11-424 Subword Modeling

Intermittent: 12 units
The goal of this course is to lead students to engage broadly with the existing NLP and computational linguistics research on subword modeling and develop new computational approaches to problems in morphology, orthography, and phonology. In addition to three other miniprojects, students will be expected to produce one piece of research that can be developed into a conference or workshop paper (though submission is not a course requirement). The paper should be suitable for the Phonology, Morphology, and Word Segmentation tracks of the *ACL conferences, the SIGMORPHON workshop, Coling, or LREC.
Prerequisites: 11-611 or 11-711 or 11-411

11-439 Designing Around Patents on Machine Learning and NLP Technology

Spring: 9 units
This course uses Machine Learning and Natural Language Processing as vehicles to teach principles in designing software to avoid patents. After introducing students to the basics of patents, we investigate how to use students software skills to design around patents that is, create new technology that avoids a patent while maintaining some, or even all, of the performance and value of the patented technology. Designing around a patent can be viewed as a puzzle that requires technical skill, understanding the business value of technology, knowledge of patents, and creativity. Students will also be able to help design patents that cannot be easily designed-around. Not only does this add a valuable new dimension to the student's skill set, the course material is organized as a vehicle for refining knowledge of ML and NLP techniques. We will practice by designing around patents on well-known ML and NLP algorithms. Students study the basic algorithm, learn the patents that cover those algorithms, and then experiment with software modifications that avoid the patent while preserving as much of the algorithm's performance as possible. In essence, students will view the presence of particular patents as a design constraints, akin to designing for limited memory, bandwidth, or processor speed. Students must have already taken courses in Natural Language Processing (e.g., 11-411) and Machine Learning (e.g., 10-315). Law of Computer Technology 17-562, 17-662, 17-762 or Patents, Licensing, and Innovation 19-473, 19-673 are helpful but not required.

11-441 Machine Learning with Graphs

Fall and Spring: 9 units
Graphs offer a natural way to represent complex relationships among objects of all kinds. Neural network learning with graphs has become important in both academic research and industrial applications. This course (for graduate and undergraduate students who meet the prerequisites) offers a mixture of fundamental concepts, algorithms, basic and advanced models, and broad applications, ranging from social popularity analysis and knowledge graph reasoning to deep learning for solving NP-complete problems.
Prerequisites: 15-213 and (21-241 or 21-341) and 21-325 and (10-701 or 10-601)

Course Website: https://cmu-ml4graph.github.io/s2024/

11-442 Search Engines

Fall: 9 units
This course studies the theory, design, and implementation of text-based search engines. The core components include statistical characteristics of text, representation of information needs and documents, several important retrieval models, and experimental evaluation. The course also covers common elements of commercial search engines, for example, integration of diverse search engines into a single search service ("federated search", "vertical search"), personalized search results, diverse search results, and sponsored search. The software architecture components include design and implementation of large-scale, distributed search engines.
Prerequisites: (36-225 or 15-259 or 21-325 or 36-218) and 15-210 Min. grade C and 15-213 Min. grade C and 21-241

Course Website: http://boston.lti.cs.cmu.edu/classes/11-642/

11-485 Introduction to Deep Learning

Intermittent: 9 units
Neural networks have increasingly taken over various AI tasks, and currently produce the state of the art in many AI tasks ranging from computer vision and planning for self-driving cars to playing computer games. Basic knowledge of NNs, known currently in the popular literature as "deep learning", familiarity with various formalisms, and knowledge of tools, is now an essential requirement for any researcher or developer in most AI and NLP fields. This course is a broad introduction to the field of neural networks and their "deep" learning formalisms. The course traces some of the development of neural network theory and design through time, leading quickly to a discussion of various network formalisms, including simple feedforward, convolutional, recurrent, and probabilistic formalisms, the rationale behind their development, and challenges behind learning such networks and various proposed solutions. We subsequently cover various extensions and models that enable their application to various tasks such as computer vision, speech recognition, machine translation and playing games. Instruction Unlike prior editions of 11-785, the instruction will primarily be through instructor lectures, and the occasional guest lecture. Evaluation Students will be evaluated based on weekly continuous-evaluation tests, and their performance in assignments and a final course project. There will be six hands-on assignments, requiring both low-level coding and toolkit-based implementation of neural networks, covering basic MLP, convolutional and recurrent formalisms, as well as one or more advanced tasks, in addition to the final project.
Prerequisites: 15-112 and 21-120 and 21-241

11-488 Concepts in Digital Multimedia and Cyber Forensics

Spring: 12 units
This course covers the use of computational methods in crime investigation (forensics) and prevention (intelligence). In almost all areas of forensics and intelligence, computational methods continue to aid, and sometimes entirely replace, human expertise in tracking crime. This is desirable since automation can address the problems associated with scale and global crime linkage through diverse data computational tools can potentially overcome and surpass human capabilities for crime investigation. This course is of a cross-disciplinary nature. It amalgamates knowledge from criminology, forensic sciences, computer science, statistics, signal processing, machine learning, AI, psychology, medicine and many other fields. Students from all departments and schools are welcome to take this course.

Course Website: https://forensics-ai.github.io/gh-syllabus/

11-490 LTI Minor Project - Seniors

All Semesters: 12 units
No course description provided.

11-492 Speech Technology for Conversational AI

Spring: 12 units
This course provides both practical and theoretical knowledge on how we can leverage speech processing technologies to build a conversational AI system. The course encompasses speech recognition, speaker recognition, speech synthesis, speech enhancement, speech translation, spoken dialogue systems, speech foundation models, and other speech and audio processing tasks. In practical sessions, students will learn to build functional speech recognition and synthesis systems or utilize existing large speech and language models and integrate them to create a speech interface using existing toolkits. The course will also present details of algorithms, techniques, evaluation metrics, and limitations of state-of-the-art speech systems. This course is particularly designed for students who want to learn how to process actual data for real-world applications, applying AI and machine learning techniques while also being aware of the current technology limitations.
Prerequisite: 15-210

11-546 Applied Legal Analytics & Artificial Intelligence

Spring: 12 units
Technological advances are affecting the legal profession and enable innovation by experts proficient in both law and AI technology. This joint course, co-taught by instructors from the University of Pittsburgh School of Law and Carnegie Mellon Universitys Language Technologies Institute, provides a hands-on practical introduction to the fields of artificial intelligence and law, machine learning, and natural language processing as they are being applied to support the work of legal professionals, researchers, and administrators, such as extracting semantic information from legal documents and using it to solve legal problems. Meanwhile, LegalTech companies and startups have been tapping into the industrys need to make large-scale document analysis tasks more efficient, and to use predictive analytics for better decision making. This course is intended to bring students of law and technical disciplines together into a collaborative classroom setting to learn about the technologies at the intersection of law and AI through lectures and programming exercises, as well as gain practical experience through collaborative project work. Topics in focus include machine learning and natural language applied to legal data, computational models of legal reasoning, and selected legal issues that relate to AI technologies. Students should come from either a (pre-) law background with a strong interest in gaining practical experience with legal analytics, or from a technical discipline with a equally strong interest in tackling the challenges posed by legal analytics tasks and data.

Course Website: https://luimagroup.github.io/appliedlegalanalytics/

11-590 LTI Minor Project - Advanced

All Semesters: 12 units
No course description provided.

11-603 Python for Data Science

Summer: 12 units
Students learn the concepts, techniques, skills, and tools needed for developing programs in Python. Core topics include types, variables, functions, iteration, conditionals, data structures, classes, objects, modules, and I/O operations. Students get an introductory experience with several development environments, including Jupyter Notebook, as well as selected software development practices, such as test-driven development, debugging, and style. Course projects include real-life applications on enterprise data and document manipulation, web scraping, and data analysis.

Course Website: https://canvas.andrew.cmu.edu

11-624 Human Language for Artificial Intelligence

Fall: 12 units
An enduring aspect of the quest to build intelligent machines is the challenge of human language. This course introduces students with a background in computer science and a research interest in artificial intelligence fields to the structure of natural language, from sound to society. It covers phonetics (the physical aspects of speech), phonology (the sound-structure of language), morphology (the structure of words), morphosyntax (the use of word and phrase structure to encode meaning), syntactic formalisms (using finite sets of production rules to characterize infinite configurations of structure), discourse analysis and pragmatics (language in discourse and communicative context), and sociolinguistics (language in social context and social meaning). Evaluation is based on seven homework assignments, a midterm examination, and a final examination.

11-630 MCDS Practicum Internship

Summer
The MCDS Practicum course is used for recording CDS students summer internships for the MCDS Program.

11-639 Designining Around Patents on Machine Learning and NLP Technology

Spring: 12 units
This course uses Machine Learning and Natural Language Processing as vehicles to teach principles in designing software to avoid patents. After introducing students to the basics of patents, we investigate how to use students software skills to design around patents that is, create new technology that avoids a patent while maintaining some, or even all, of the performance and value of the patented technology. Designing around a patent can be viewed as a puzzle that requires technical skill, understanding the business value of technology, knowledge of patents, and creativity. Students will also be able to help design patents that cannot be easily designed-around. Not only does this add a valuable new dimension to the students skill set, the course material is organized as a vehicle for refining knowledge of ML and NLP techniques. We will practice by designing around patents on well-known ML and NLP algorithms. Students study the basic algorithm, learn the patents that cover those algorithms, and then experiment with software modifications that avoid the patent while preserving as much of the algorithms performance as possible. In essence, students will view the presence of particular patents as a design constraints, akin to designing for limited memory, bandwidth, or processor speed. Students must have already taken courses in Natural Language Processing (e.g., 11-411) and Machine Learning (e.g., 10-315). Law of Computer Technology 17-562, 17-662, 17-762 or Patents, Licensing, and Innovation 19-473, 19-673 are helpful but not required.

11-646 Applied Legal Analytics & Artificial Intelligence

Spring: 12 units
Technological advances are affecting the legal profession and enable innovation by experts proficient in both law and AI technology. This joint course, co-taught by instructors from the University of Pittsburgh School of Law and Carnegie Mellon Universitys Language Technologies Institute, provides a hands-on practical introduction to the fields of artificial intelligence and law, machine learning, and natural language processing as they are being applied to support the work of legal professionals, researchers, and administrators, such as extracting semantic information from legal documents and using it to solve legal problems. Meanwhile, LegalTech companies and startups have been tapping into the industrys need to make large-scale document analysis tasks more efficient, and to use predictive analytics for better decision making. This course is intended to bring students of law and technical disciplines together into a collaborative classroom setting to learn about the technologies at the intersection of law and AI through lectures and programming exercises, as well as gain practical experience through collaborative project work. Topics in focus include machine learning and natural language applied to legal data, computational models of legal reasoning, and selected legal issues that relate to AI technologies. Students should come from either a (pre-) law background with a strong interest in gaining practical experience with legal analytics, or from a technical discipline with a equally strong interest in tackling the challenges posed by legal analytics tasks and data.

Course Website: https://luimagroup.github.io/appliedlegalanalytics/

11-661 Language and Statistics

Fall: 12 units
Language technologies (search, text mining, information retrieval, speech recognition, machine translation, question answering, biological sequence analysis...) are at the forefront of this century's information revolution. In addition to their use of machine learning, these technologies rely centrally on classic statistical estimation techniques. Yet most CS and engineering undergraduate programs do not prepare students in this area beyond an introductory prob and amp;stats course. This course is designed to plug this hole. The goal of "Language and Statistics" is to ground the data-driven techniques used in language technologies in sound statistical methodology. We start by formulating various language technology problems in both an information theoretic framework (the source-channel paradigm) and a Bayesian framework (the Bayes classifier). We then discuss the statistical properties of words, sentences, documents and whole languages, and the computational formalisms used to represent language. These discussions naturally lead to specific concepts in statistical estimation. Topics include: Zipf's distribution and type-token curves; point estimators, Maximum Likelihood estimation, bias and variance, sparseness, smoothing and clustering; interpolation, shrinkage, and backoff; entropy, cross entropy and mutual information; decision tree models applied to language; latent variable models and the EM algorithm; hidden Markov models; exponential models and maximum entropy; semantic modeling and dimensionality reduction; probabilistic context-free grammars and syntactic language models. The course is designed for LTI and amp; SCS graduate students, but others are welcome. CS UG upperclassmen who've taken it have done well, though they found it challenging. The 11-661 version does not require the course project. Prerequisites: Strong quantitative aptitude. Comfort with basic UG-level probability. Some programming skill.

Course Website: http://www.cs.cmu.edu/~roni/11661/

11-667 Large Language Models Methods and Application

Fall: 12 units
This course provides a broad foundation for understanding, working with, and adapting existing tools and technologies in the area of Large Language Models like BERT, T5, GPT, and others. It begins with a short history of the area of language models and quickly transitions to a broad survey of the area, offering exposure to the gamut of topics including systems, data, data filtering, training objectives, RLHF/instruction tuning, ethics, policy, evaluation, and other human facing issues. Students will delve into Transformer architectures more broadly and how they work, as well as exploring the reasons why they are better than LSTM-based seq2seq, decoding strategies, etc. Students will learn through readings and hands-on assignments where they will explore techniques for pretraining, attention, prompting, etc. They will then apply these skills in a semester-long course project, making use of locally sourced model instances that offer the opportunity to explore behind the curtain of commercial APIs.
Prerequisites: 11-711 or 11-785 or 11-685 or 10-701 or 10-601

11-696 MIIS Capstone Planning Seminar

Spring: 6 units
The MIIS Capstone Planning Seminar prepares students to complete the MIIS Capstone Project in the following semester. Students are organized into teams that will work together to complete the capstone project. They define project goals, requirements, success metrics, and deliverables; and they identify and acquires data, software, and other resources required for successful completion of the project. The planning seminar must be completed in the semester prior to taking the capstone project.

11-697 Introduction to Question Answering with Large Language Models

Fall: 12 units
This course is designed to be accessible to Masters and advanced undergraduate students who seek the basic skills necessary to implement practical Question Answering (QA) applications using Large Language Models (LLMs) in specific information domains. The syllabus includes learning materials on the core concepts of QA and LLMs, and how they are applied in closed commercial systems (e.g. ChatGPT) as well as open systems (e.g. Llama, T5). Students complete a set of hands-on exercises in Python that develop skills in applying LLMs for various open-source QA datasets. The course is also a prerequisite for 11-797 Question Answering (an advanced project-oriented course).

Course Website: https://www.cs.cmu.edu/~ehn/11-697/

11-711 Advanced Natural Language Processing

Fall: 12 units
Advanced natural language processing is an introductory graduate-level course on natural language processing aimed at students who are interested in doing cutting-edge research in the field. In it, we describe fundamental tasks in natural language processing such as syntactic, semantic, and discourse analysis, as well as methods to solve these tasks. The course focuses on modern methods using neural networks, and covers the basic modeling and learning algorithms required therefore. The class culminates in a project in which students attempt to reimplement and improve upon a research paper in a topic of their choosing.

11-716 Graduate Seminar on Dialog Processing

All Semesters: 6 units
Dialog systems and processes are becoming an increasingly vital area of interest both in research and in practical applications. The purpose of this course will be to examine, in a structured way, the literature in this area as well as learn about ongoing work. The course will cover traditional approaches to the problem, as exemplified by the work of Grosz and Sidner, as well as more recent work in dialog, discourse and evaluation, including statistical approaches to problems in the field. We will select several papers on a particular topic to read each week. While everyone will do all readings, a presenter will be assigned to overview the paper and lead the discussion. On occasion, a researcher may be invited to present their own work in detail and discuss it with the group. A student or researcher taking part in the seminar will come away with a solid knowledge of classic work on dialog, as well as familiarity with ongoing trends.

11-721 Grammars and Lexicons

All Semesters: 12 units
Grammars and Lexicons is an introductory graduate course on linguistic data analysis and theory, focusing on methodologies that are suitable for computational implementations. The course covers major syntactic and morphological phenomena in a variety of languages. The emphasis will be on examining both the diversity of linguistic structures and the constraints on variation across languages. Students will be expected to develop and defend analyses of data, capturing linguistic generalizations and making correct predictions within and across languages. The goal is for students to become familiar with the range of phenomena that occur in human languages so that they can generalize the insights into the design of computational systems. The theoretical framework for syntactic and lexical analysis will be Lexical Functional Grammar. Grades will be based on problem sets and take-home exams.

11-722 Grammar Formalisms

Intermittent: 12 units
The goal of this course is to familiarize students with grammar formalisms that are commonly used for research in computational lingusitics, language technologies, and lingusitics. We hope to have students from a variety disciplines (linguistics, computer science, psychology, modern languages, philosophy) in order to cover a broad perspective in class discussions. Comparison of formalisms will lead to a deeper understanding of human language and natural language processing algorithms. The formalisms will include: Head Driven Phrase Structure Grammar, Lexical Functional Grammar, Tree Adjoining Grammar and Categorial Grammar. If time permits, we will cover Penn Treebank, dependency grammar, and Construction Grammar. We will cover the treatment of basic syntactic and semantic phenomena in each formalism, and will also discuss algorithms for parsing and generating sentences for each formalism. If time permits, we may discuss formal language theory and generative capacity. The course is taught jointly by the following faculty of the Language Technologies Institute: Alan Black Alon Lavie Lori Levin (main coordinator)

11-724 Human Language for Artificial Intelligence

Fall: 12 units
An enduring aspect of the quest to build intelligent machines is the challenge of human language. This course introduces students with a background in computer science and a research interest in artificial intelligence fields to the structure of natural language, from sound to society. It covers phonetics (the physical aspects of speech), phonology (the sound-structure of language), morphology (the structure of words), morphosyntax (the use of word and phrase structure to encode meaning), syntactic formalisms (using finite sets of production rules to characterize infinite configurations of structure), discourse analysis and pragmatics (language in discourse and communicative context), and sociolinguistics (language in social context and social meaning). Evaluation is based on seven homework assignments, a midterm examination, and a final examination.

Course Website: http://www.lti.cs.cmu.edu/Courses/11-724-desc.htm

11-731 Machine Translation and Sequence-to-Sequence Models

Spring: 12 units
Instructors: Graham Neubig. Prerequisites: This course has no official pre-requisites, although 11-711 "Algorithms for NLP" or 10-701 "Machine Learning" would be helpful. Course Description: Machine Translation and Sequence-to-Sequence Models is an introductory graduate-level course surveying the primary approaches and methods for developing systems to translate between human languages, or other sequential data. The main objective of the course is to obtain basic understanding and implementation skills for modern methods for MT and sequence transduction, including how to design models, how to learn the model parameters, how to search for the best output, and how to create training data. The course will focus on machine translation, but also briefly cover tasks such as dialog response generation, image caption generation, and others.

11-737 Multilingual Natural Language Processing.

Fall: 12 units
11737 Multilingual Natural Language Processing is an advanced graduate-level course on natural language processing techniques applicable to many languages. Students who take this course should be able to develop linguistically motivated solutions to core and applied NLP tasks for any language. This includes understanding and mitigating the difficulties posed by lack of data in low-resourced languages or language varieties, and the necessity to model particular properties of the language of interest such as complex morphology or syntax. The course will introduce modeling solutions to these issues such as multilingual or cross-lingual methods, linguistically informed NLP models, and methods for effectively bootstrapping systems with limited data or human intervention. The project work will involve building an end-to-end NLP pipeline in a language you don't know.

Course Website: https://www.cs.cmu.edu/~leili/course/11737mnlp23fa/

11-739 Designing Around Patents on Machine Learning and NLP Technology

Spring: 12 units
This course uses Machine Learning and Natural Language Processing as vehicles to teach principles in designing software to avoid patents. After introducing students to the basics of patents, we investigate how to use students software skills to design around patents that is, create new technology that avoids a patent while maintaining some, or even all, of the performance and value of the patented technology. Designing around a patent can be viewed as a puzzle that requires technical skill, understanding the business value of technology, knowledge of patents, and creativity. Students will also be able to help design patents that cannot be easily designed-around. Not only does this add a valuable new dimension to the student's skill set, the course material is organized as a vehicle for refining knowledge of ML and NLP techniques. We will practice by designing around patents on well-known ML and NLP algorithms. Students study the basic algorithm, learn the patents that cover those algorithms, and then experiment with software modifications that avoid the patent while preserving as much of the algorithm's performance as possible. In essence, students will view the presence of particular patents as a design constraints, akin to designing for limited memory, bandwidth, or processor speed. Students must have already taken courses in Natural Language Processing (e.g., 11-411) and Machine Learning (e.g., 10-315). Law of Computer Technology 17-562, 17-662, 17-762 or Patents, Licensing, and Innovation 19-473, 19-673 are helpful but not required.

11-741 Machine Learning with Graphs

Fall and Spring: 12 units
Graphs offer a natural way to represent complex relationships among objects of all kinds. Neural network learning with graphs has become important in both academic research and industrial applications. This course (for graduate and undergraduate students who meet the prerequisites) offers a mixture of fundamental concepts, algorithms, basic and advanced models, and broad applications, ranging from social popularity analysis and knowledge graph reasoning to deep learning for solving NP-complete problems.
Prerequisites: 15-213 and (21-241 or 21-341) and 21-325 and (10-601 or 10-701)

Course Website: https://cmu-ml4graph.github.io/s2024/

11-747 Neural Networks for NLP

All Semesters: 12 units
Neural networks provide powerful new tools for modeling language, and have been used both to improve the state-of-the-art in a number of tasks and to tackle new problems that were not easy in the past. This class will start with a brief overview of neural networks, then spend the majority of the class demonstrating how to apply neural networks to natural language problems. Each section class will introduce a particular problem or phenomenon in natural language, describe why it is difficult to model, and demonstrate several models that were designed to tackle this problem. In the process of doing so, the class will cover different techniques that are useful in creating models, including handling variably sized and structured sentences, efficient handling of large data, semi-supervised and unsupervised learning, structured prediction, and multilingual modeling. There are no official pre-requisites, but a natural language processing course such as 11-411, 11-611, or 11-711, or other experience with implementing natural language processing models is highly recommended.

11-751 Speech Recognition and Understanding

All Semesters: 12 units
The technology to allow humans to communicate by speech with machines or by which machines can understand when humans communicate with each other is rapidly maturing. This course provides an introduction to the theoretical tools as well as the experimental practice that has made the field what it is today. We will cover theoretical foundations, essential algorithms, major approaches, experimental strategies and current state-of-the-art systems and will introduce the participants to ongoing work in representation, algorithms and interface design. This course is suitable for graduate students with some background in computer science and electrical engineering, as well as for advanced undergraduates. Prerequisites: Sound mathematical background, knowledge of basic statistics, good computing skills. No prior experience with speech recognition is necessary. This course is primarily for graduate students in LTI, CS, Robotics, ECE, Psychology, or Computational Linguistics. Others by prior permission of instructor.

11-752 Speech II: Phonetics, Prosody, Perception and Synthesis

Spring: 12 units
The goal of the course is to give the student basic knowledge from several fields that is necessary in order to pursue research in automatic speech processing. The course will begin with a study of the acoustic content of the speech signal. The students will use the spectrographic display to examine the signal and discover its variable properties. Phones in increasingly larger contexts will be studied with the goal of understanding coarticulation. Phonological rules will be studied as a contextual aid in understanding the spectrographic display. The spectrogram will then serve as a first introduction to the basic elements of prosody. Other displays will then be used to study the three parts of prosody: amplitude, duration, and pitch. Building on these three elements, the student will then examine how the three interact in careful and spontaneous speech. Next, the students will explore perception. Topics covered will be: physical aspects of perception, psychological aspects of perception, testing perception processes, practical applications of knowledge about perception. The second part of this course will cover all aspects of speech synthesis. Students need only have a basic knoweldge of speech and language processing. Some degree of programming and statistical modelling will be beneficial, but not required. Taught every other year

11-755 Machine Learning for Signal Processing

Fall: 12 units
Signal Processing is the science that deals with extraction of information from signals of various kinds. This has two distinct aspects and #8212; characterization and categorization. Traditionally, signal characterization has been performed with mathematically-driven transforms, while categorization and classification are achieved using statistical tools. Machine learning aims to design algorithms that learn about the state of the world directly from data. A increasingly popular trend has been to develop and apply machine learning techniques to both aspects of signal processing, often blurring the distinction between the two. This course discusses the use of machine learning techniques to process signals. We cover a variety of topics, from data driven approaches for characterization of signals such as audio including speech, images and video, and machine learning methods for a variety of speech and image processing problems.

11-761 Language and Statistics

Fall: 12 units
Language technologies (search, text mining, information retrieval, speech recognition, machine translation, question answering, biological sequence analysis...) are at the forefront of this century's information revolution. In addition to their use of machine learning, these technologies rely centrally on classic statistical estimation techniques. Yet most CS and engineering undergraduate programs do not prepare students in this area beyond an introductory prob and amp;stats course. This course is designed to plug this hole. The goal of "Language and Statistics" is to ground the data-driven techniques used in language technologies in sound statistical methodology. We start by formulating various language technology problems in both an information theoretic framework (the source-channel paradigm) and a Bayesian framework (the Bayes classifier). We then discuss the statistical properties of words, sentences, documents and whole languages, and the computational formalisms used to represent language. These discussions naturally lead to specific concepts in statistical estimation. Topics include: Zipf's distribution and type-token curves; point estimators, Maximum Likelihood estimation, bias and variance, sparseness, smoothing and clustering; interpolation, shrinkage, and backoff; entropy, cross entropy and mutual information; decision tree models applied to language; latent variable models and the EM algorithm; hidden Markov models; exponential models and maximum entropy; semantic modeling and dimensionality reduction; probabilistic context-free grammars and syntactic language models. The course is designed for LTI and amp; SCS graduate students, but others are welcome. CS UG upperclassmen who've taken it have done well, though they found it challenging. The 11-661 version does not require the course project. Prerequisites: Strong quantitative aptitude. Comfort with basic UG-level probability. Some programming skill.

Course Website: http://www.cs.cmu.edu/~roni/11761/

11-762 Language and Statistics II

Fall: 12 units
This course will cover modern empirical methods in natural language processing. It is designed for language technologies students who want to understand statistical methodology in the language domain, and for machine learning students who want to know about current problems and solutions in text processing. Students will, upon completion, understand how statistical modeling and learning can be applied to text, be able to develop and apply new statistical models for problems in their own research, and be able to critically read papers from the major related conferences (EMNLP and ACL). A recurring theme will be the tradeoffs between computational cost, mathematical elegance, and applicability to real problems. The course will be organized around methods, with concrete tasks introduced throughout. The course is designed for SCS graduate students. Prerequisite: Language and Statistics (11-761) or permission of the instructor. Recommended: Algorithms for Natural Language Processing (11-711), Machine Learning (15-681, 15-781, or 11-746).
Prerequisite: 11-761

11-763 Structured Prediction for Language and other Discrete Data

Fall: 12 units
This course seeks to cover statistical modeling techniques for discrete, structured data such as text. It brings together content previously covered in Language and Statistics 2 (11-762) and Information Extraction (10-707 and 11-748), and aims to define a canonical set of models and techniques applicable to problems in natural language processing, information extraction, and other application areas. Upon completion, students will have a broad understanding of machine learning techniques for structured outputs, will be able to develop appropriate algorithms for use in new research, and will be able to critically read related literature. The course is organized around methods, with example tasks introduced throughout.

Course Website: http://www.cs.cmu.edu/~nasmith/SPFLODD/

11-776 Multimodal Affective Computing

Fall: 12 units
Humans are highly social creatures and have evolved complex mechanisms for signaling information about their thoughts, feelings, and intentions (both deliberately and reflexively). In turn, humans have also evolved complex mechanisms for receiving these signals and inferring the thoughts, feelings, and intentions of others. Proper understanding of human behavior, in all its nuance, requires careful consideration and integration of verbal, vocal, and visual information. These communication dynamics have long been studied in psychology and other social sciences. More recently, the field of multimodal affective computing has sought to enhance these studies using techniques from computer science and artificial intelligence. Common topics of study in this field include affective states, cognitive states, personality, psychopathology, social processes, and communication. As such, multimodal affective computing has broad applicability in both scientific and applied settings ranging from medicine and education to robotics and marketing. The objectives of this course are: (1) To give an overview of the components of human behavior (verbal, vocal, and visual) and the computer science areas that measure them (NLP, speech processing, and computer vision) (2) To provide foundational knowledge of psychological constructs commonly studied in multimodal affective computing (e.g., emotion, personality, and psychopathology) (3) To provide practical instruction on using statistical tools to study research hypotheses (4) To provide information about computational predictive models that integrate multimodal information from the verbal, vocal, and visual modalities (5) To give students practical experience in the computational study of human behavior and psychological constructs through an in-depth course project

11-777 Multimodal Machine Learning

Fall: 12 units
Multimodal machine learning (MMML) is a vibrant multi-disciplinary research field which addresses some of the original goals of artificial intelligence by integrating and modeling multiple communicative modalities, including linguistic, acoustic and visual messages. With the initial research on audio-visual speech recognition and more recently with language vision projects such as image and video captioning, this research field brings some unique challenges for multimodal researchers given the heterogeneity of the data and the contingency often found between modalities. The course will present the fundamental mathematical concepts in machine learning and deep learning relevant to the five main challenges in multimodal machine learning: (1) multimodal representation learning, (2) translation and amp; mapping, (3) modality alignment, (4) multimodal fusion and (5) co-learning. These include, but not limited to, multimodal auto-encoder, deep canonical correlation analysis, multi-kernel learning, attention models and multimodal recurrent neural networks. We will also review recent papers describing state-of-the-art probabilistic models and computational algorithms for MMML and discuss the current and upcoming challenges. The course will discuss many of the recent applications of MMML including multimodal affect recognition, image and video captioning and cross-modal multimedia retrieval. This is a graduate course designed primarily for PhD and research master students at LTI, MLD, CSD, HCII and RI; others, for example (undergraduate) students of CS or from professional master programs, are advised to seek prior permission of the instructor. It is required for students to have taken an introduction machine learning course such as 10-401, 10-601, 10-701, 11-663, 11-441, 11-641 or 11-741. Prior knowledge of deep learning is recommended."

Course Website: https://piazza.com/cmu/fall2018/11777/home (https://piazza.com/cmu/fall2018/11777/home/)

11-792 Intelligent Information Systems Project - HEINZ STUDENTS ONLY

Spring: 12 units
The Software Engineering for IS sequence combines classroom material and assignments in the fundamentals of software engineering (11-791) with a self-paced, faculty-supervised directed project (11-792). The two courses cover all elements of project design, implementation, evaluation, and documentation. Students may elect to take only 11-791; however, if both parts are taken, they should be taken in proper sequence. Prerequisite: 11-791. The course is required for VLIS students.
Prerequisites: 11-791 or 15-393

11-801 Quantitative Evaluation of Language Technologies

Spring: 12 units
Evaluating NLP models for properties like quality, fluency, safety, or revenue generation is a fundamental part of model development in research and engineering contexts. This course will present fundamental principles of evaluation, focusing on both offline contexts such as benchmark datasets and online environments such as production systems. Material will be organized into two parts. The first part will focus on measurement of system decisions, covering the principles of metric design (i.e., what makes a metric appropriate for a given NLP task), data elicitation (i.e., how can we gather data associated with what we are trying to measure), and modeling system properties (i.e., how can we formally model the properties like quality). The second part will focus on comparing systems given a set of measured values. We will cover dataset construction and hypothesis testing in both offline and online contexts. The course will include lectures from external researchers and practitioners using evaluation techniques to audit systems, design new benchmarks, and deploy production models.

11-824 Subword Modeling

Intermittent: 12 units
The goal of this course is to lead students to engage broadly with the existing NLP and computational linguistics research on subword modeling and develop new computational approaches to problems in morphology, orthography, and phonology. In addition to three other miniprojects, students will be expected to produce one piece of research that can be developed into a conference or workshop paper (though submission is not a course requirement). The paper should be suitable for the Phonology, Morphology, and Word Segmentation tracks of the *ACL conferences, the SIGMORPHON workshop, Coling, or LREC.
Prerequisites: 11-711 or 11-611 or 11-411

11-851 Talking to Robots

Fall
Household robots need to move beyond simple programmed tasks like those a roomba, and become full-fledged digital assistants. A robotic agent that exists (physically) in the world, gains access to rich and personalized knowledge of its environment. How much do things weigh? What's fragile? Where you store the extra chocolates that you don't want anyone to find because they are just for you. Building an agent that can accomplish tasks requires the integration of a diverse set of technologies and engineering. Language models, SLAM, semantic mapping, task planning, understanding affordances, and end effector control. This course will cover both foundational works in grounding language to action and analyze (or reimplement) state-of-the-art Large Language Model based task planners.

Course Website: https://talkingtorobots.com/11-851/

11-868 Large Language Model Systems

Spring: 12 units
Recent progress of Artificial Intelligence has been largely driven by advances in large language models (LLMs) and other generative methods. These models are often very large (e.g. 175 billion parameters for GPT3) and requires increasingly larger data to train (e.g. 300 billion tokens for ChatGPT). Training, serving, fine-tuning, and evaluating LLMs require sophisticated engineering with modern hardware and software stacks. Developing scalable systems for large language models is critical to advance AI. In this course, students will learn the essential skills to design and implement LLM systems. This includes algorithms and system techniques to efficiently train LLMs with huge data, efficient embedding storage and retrieval, data efficient fine-tuning, communication efficient algorithms, efficient implementation of reinforcement learning with human feedback, acceleration on GPU and other hardware, model compression for deployment, and online maintenance. We will cover the latest advances about LLM systems in machine learning, natural language processing, and system research.
Prerequisites: 11-711 and 11-785

Course Website: https://llmsystem.github.io/

11-877 Advanced Topics in Multimodal Machine Learning

Spring
This course is designed to be a graduate-level course covering recent research papers in multimodal machine learning, a vibrant multi-disciplinary research field which studies modeling, alignment, and fusion of heterogeneous data from multiple modalities, including language, vision, and acoustic. The course will focus on discussions and understanding of recent research papers in this field. Students are expected to have already taken 11-777 Multimodal Machine Learning course or have equivalent research experience (instructor approval required). The course is planned for 6 credit units. Optionally, students can register for 12 credit units, with the expectation to do a comprehensive research project as part of the semester. These course projects are expected to be done in teams, with the research topic to be in the realm of multimodal machine learning and pre-approved by the course instructors.
Prerequisite: 11-777 Min. grade C

11-891 Neural Code Generation

Spring
This course is a graduate-level course introducing research topics in neural code generation: modeling and synthesizing programs using deep-learning methods, with an emphasis on neural language models. The course covers (1) foundational advances in neural language models that are relevant to code generation (2) code-specific formal methods for training, inference, and evaluation and (3) research frontiers such as long document lengths, domain adaptation, and downstream interactive and production-ready uses of the final code generation models. The course combines lectures and paper discussions, as well as a final research project for students taking the course for 12 units. This is a graduate course designed primarily for PhD and research master students at LTI, S3D, MLD, CSD, HCII and RI; others, for example (undergraduate) students of CS or from professional master programs, are advised to seek prior permission of the instructors. It is required for students to have taken an introductory ML course or an ML project-based course such as 10-401, 10-601, 10-701, 11-663, 11-441, 11-641, 11-667, 11-741, 11-711, or 11-777. Prior knowledge of deep learning is recommended.

11-927 MIIS Capstone Project

Fall: 36 units
The capstone project course is a group-oriented demonstration of student skill in one or more areas covered by the degree. Typically the result of the capstone project is a major software application. The capstone project course consists of two components. The classroom component guides students in project planning, team management, development of requirements and design specifications, and software tools for managing group-oriented projects. The lab component provides project-specific technical guidance and expertise, for example in the development of a question answering system, dialog, or sentiment analysis application. Thus, each project receives two types of supervision, often from two separate members of the faculty.

Machine Learning Courses

10-301 Introduction to Machine Learning

Fall and Spring: 12 units
Machine Learning is concerned with computer programs that automatically improve their performance through experience (e.g., programs that learn to recognize human faces, recommend music and movies, and drive autonomous robots). This course covers the theory and practical algorithms for machine learning from a variety of perspectives. We cover topics such as decision tree learning, neural networks, statistical learning methods, unsupervised learning and reinforcement learning. The course covers theoretical concepts such as inductive bias, the PAC learning framework, Bayesian learning methods, and Occam's Razor. Programming assignments include hands-on experiments with various learning algorithms. This course is designed to give a graduate-level student a thorough grounding in the methodologies, technologies, mathematics and algorithms currently needed by people who do research in machine learning. 10-301 and 10-601 are identical. Undergraduates must register for 10-301 and graduate students must register for 10-601. 10-301 is recommended for undergraduates who are not SCS majors. (SCS majors should instead take 10-315.)
Prerequisites: 15-122 Min. grade C and (15-151 Min. grade C or 21-128 Min. grade C or 21-127 Min. grade C) and (36-217 Min. grade C or 21-325 Min. grade C or 36-235 Min. grade C or 15-359 Min. grade C or 36-218 Min. grade C or 36-225 Min. grade C or 36-220 Min. grade C or 15-259 Min. grade C or 36-219 Min. grade C)

Course Website: http://mlcourse.org

10-315 Introduction to Machine Learning (SCS Majors)

Fall and Spring: 12 units
Machine learning is a subfield of computer science with the goal of exploring, studying, and developing learning systems, methods, and algorithms that can improve their performance with learning from data. This course is designed to give undergraduate students a one-semester-long introduction to the main principles, algorithms, and applications of machine learning and is specifically designed for the SCS undergrad majors. After completing the course, students will be able to: *select and apply an appropriate supervised learning algorithm for classification problems and understand its underlying assumptions (e.g., naive Bayes, perceptron, support vector machine, logistic regression). *select and apply an appropriate supervised learning algorithm for regression problems and understand its underlying assumptions (e.g., linear regression, ridge regression). *recognize different types of unsupervised learning problems, and select and apply appropriate algorithms (e.g., clustering, linear and nonlinear dimensionality reduction). *work with probabilities (Bayes rule, conditioning, expectations, independence), linear algebra (vector and matrix operations, eigenvectors), and calculus (gradients) to derive machine learning methods such as linear regression, naive Bayes, and principal components analysis. *understand machine learning principles such as model selection, overfitting, and underfitting, and techniques such as cross-validation and regularization. *implement machine learning algorithms such as logistic regression via stochastic gradient descent, linear regression (using a linear algebra toolbox), perceptron, or k-means clustering. *run appropriate supervised and unsupervised learning algorithms on real and synthetic data sets and interpret the results.
Prerequisites: 15-122 Min. grade C and (21-128 Min. grade C or 15-151 Min. grade C or 21-127 Min. grade C) and (15-259 Min. grade C or 21-325 Min. grade C or 15-359 Min. grade C or 36-219 Min. grade C or 36-235 Min. grade C or 36-217 Min. grade C or 36-225 Min. grade C or 36-218 Min. grade C) and (21-240 Min. grade C or 21-241 Min. grade C or 21-242 Min. grade C)

Course Website: https://goo.gl/mmR2eL (https://goo.gl/mmR2eL/)

10-335 Art and Machine Learning

Intermittent: 12 units
ARS, the Latin origin of the word 'art', encompasses both Art and Science. Over time, these two disciplines, once separated, are now converging in various area. One such intersection is the fusion of art and machine learning. In recent years, art has been propelled forward by the rapid advancements in technology and scientific discoveries, while machine learning (ML) stands at the forefront of computer science innovation. The increasing popularity and accessibility of neural network-based AI models have garnered significant attention for the amalgamation of art and ML techniques. This project-based course is designed to introduce the synergy between art and machine learning to a wide range of students, including majoring in art and computer science. We will impart knowledge through examples, technologies, and discussions that bridge the realms of art and machine learning. Students will explore example codes and make creative applications and artworks using ML methods. No prior knowledge of machine learning or experience in art practice is required, but students should have a basic understanding of Python. Additionally, an open-minded approach is essential, as occasionally we will delve into the necessary mathematical foundations and engage in discussions on the conceptual development and artistic value of your projects.

Course Website: https://sites.google.com/view/artml23s (https://sites.google.com/view/artml23s/)

10-403 Deep Reinforcement Learning & Control

Spring: 12 units
This course brings together many disciplines of Artificial Intelligence (including computer vision, robot control, reinforcement learning, language understanding) to show how to develop intelligent agents that can learn to sense the world and learn to act by imitating others, maximizing sparse rewards, and/or satisfying their curiosity.
Prerequisites: 10-401 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C or 10-601 Min. grade C or 10-701 Min. grade C

Course Website: https://cmudeeprl.github.io/Spring202010403website/

10-405 Machine Learning with Large Datasets (Undergraduate)

Spring: 12 units
Large datasets are difficult to work with for several reasons. They are difficult to visualize, and it is difficult to understand what sort of errors and biases are present in them. They are computationally expensive to process, and often the cost of learning is hard to predict - for instance, and algorithm that runs quickly in a dataset that fits in memory may be exorbitantly expensive when the dataset is too large for memory. Large datasets may also display qualitatively different behavior in terms of which learning methods produce the most accurate predictions. This course is intended to provide a student practical knowledge of, and experience with, the issues involving large datasets. Among the issues considered are: scalable learning techniques, such as streaming machine learning techniques; parallel infrastructures such as map-reduce; practical techniques for reducing the memory requirements for learning methods, such as feature hashing and Bloom filters; and techniques for analysis of programs in terms of memory, disk usage, and (for parallel methods) communication complexity. The class will include programming assignments, and a one-month short project chosen by the student. The project will be designed to compare the scalability of variant learning algorithms on datasets. An introductory course in machine learning, like 10-601 or 10-701, is a prerequisite or a co-requisite. If you plan to take this course and 10-601 concurrently please tell the instructor. The course will include several substantial programming assignments, so an additional prerequisite is 15-211, or 15-214, or comparable familiarity with Python and good programming skills.
Prerequisites: (15-211 or 17-214 or 15-214 or 15-210) and (10-401 or 10-301 or 10-715 or 10-701 or 10-315 or 10-601)

Course Website: https://10605.github.io/

10-414 Deep Learning Systems: Algorithms and Implementation

Intermittent: 12 units
The goal of this course is to provide students an understanding and overview of the "full stack" of deep learning systems, ranging from the high-level modeling design of modern deep learning systems, to the basic implementation of automatic differentiation tools, to the underlying device-level implementation of efficient algorithms. Throughout the course, students will design and build from scratch a complete deep learning library, capable of efficient GPU-based operations, automatic differentiation of all implemented functions, and the necessary modules to support parameterized layers, loss functions, data loaders, and optimizers. Using these tools, students will then build several state-of-the-art modeling methods, including convolutional networks for image classification and segmentation, recurrent networks and self-attention models for sequential tasks such as language modeling, and generative models for image generation.
Prerequisites: (15-213 Min. grade C or 15-513 Min. grade C) and (21-240 Min. grade C or 21-241 Min. grade C) and (15-151 Min. grade C or 21-127 Min. grade C or 21-128 Min. grade C) and (10-301 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C or 10-315 Min. grade C or 10-715 Min. grade C)

10-417 Intermediate Deep Learning

Fall: 12 units
Building intelligent machines that are capable of extracting meaningful representations from data lies at the core of solving many AI related tasks. In the past decade, researchers across many communities, from applied statistics to engineering, computer science and neuroscience, have developed deep models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. The goal of this course is to introduce students to both the foundational ideas and the recent advances in deep learning. The first part of the course will focus on supervised learning, including neural networks, back-propagation algorithm, convolutional models, recurrent neural networks, and their extensions with applications to image recognition, video analysis, and language modelling. The second part of the course will cover unsupervised learning, including variational autoencoders, sparse-coding, Boltzmann machines, and generative adversarial networks. This course will assume a reasonable degree of mathematical maturity and will require strong programming skills.

Prerequisites: 10-701 Min. grade C or 10-601 Min. grade C or 10-301 Min. grade C or 10-315 Min. grade C or 10-715 Min. grade C

Course Website: https://deeplearning-cmu-10417.github.io

10-418 Machine Learning for Structured Data

Intermittent: 12 units
A key challenge in machine learning is that of structured prediction: taking unstructured data as input and producing a structured output. Structured prediction problems abound throughout application areas such as natural language processing, speech processing, computational biology, computer vision, healthcare, and many others. In this course, we will study modern approaches to structured prediction building on probabilistic graphical models, deep learning, and search. The course will focus on three key aspects: models, inference, and learning. The models we consider will focus on both generative and discriminative models such as Bayesian networks, Markov random fields (MRFs), conditional random fields (CRFs), and deep neural networks including convolutional neural networks (CNNs) and recurrent neural networks (RNNs) and #8212; as well as hybrids of graphical models and neural networks. The course will explore approaches to exact and approximate inference: junction tree algorithm, approximate marginal inference by Markov chain Monte Carlo (MCMC) and variational methods, approximate MAP inference by integer linear programming (ILP) and search. We will explore unsupervised, semi-supervised, and supervised learning using different formulations of the learning problem: MLE, Bayesian inference, structured perceptron, M3Ns, learning to search, and autoencoders. Covered applications will include machine translation, speech recognition, DNA sequence analysis, scene understanding, medical diagnosis. This course is cross-listed as 10-418 and 10-618; students registered for 10-618 will do a course project.
Prerequisites: 10-715 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C or 10-401 Min. grade C or 10-301 Min. grade C or 10-315 Min. grade C

10-422 Foundations of Learning, Game Theory, and Their Connections

Intermittent: 12 units
In the past decades, researchers have discovered a number of important and deep connections between machine learning theory and algorithmic game theory. This course will explore these connections, both introducing fundamental topics in each area and describing how ideas from each area can shed light on the other.
Prerequisites: (36-218 Min. grade C or 36-217 Min. grade C or 15-259 Min. grade C or 21-325 Min. grade C or 36-225 Min. grade C or 36-219 Min. grade C) and (15-251 Min. grade C or 10-601 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C) and (21-240 Min. grade C or 21-241 Min. grade C or 21-242 Min. grade C)

10-423 Generative AI

Intermittent: 12 units
From generating images and text to generating music and art, the goal of generative modeling has long been a key challenge for artificial intelligence. This course explores the techniques from machine learning and artificial intelligence that are driving the recent advances in generative modeling and foundation models. Students will understand, develop, and apply state-of-the-art algorithms that enable machines to generate realistic and creative content. Core topics will include: the fundamental mechanisms of learning; how to build generative models and other large foundation models (e.g. transformers for vision and language, diffusion models); how to train such models (pre-training, fine-tuning) and efficiently adapt them (adapters, in-context learning); how to scale up to massive datasets (multi-GPU/distributed optimization); how to employ existing models for everyday use (generating code, coding with a generative model in the loop). Students will also explore the theoretical foundations and empirical attempts to understand their inner workings as well as learn about the ways in which things can go wrong (bias, hallucination, adversarial attacks, data contamination) and ways to combat these problems. Students in the course will develop understanding of modern techniques through implementation, but they will also employ existing libraries and models to explore their generative capabilities and limitations. The course is designed for students who have completed an introductory course in machine learning or deep learning.
Prerequisites: 10-601 Min. grade C or 10-701 Min. grade C or 10-715 Min. grade C or 11-485 Min. grade C or 11-685 Min. grade C or 10-301 Min. grade C or 11-785 Min. grade C or 10-315 Min. grade C

Course Website: https://www.cs.cmu.edu/~mgormley/courses/10423 (https://www.cs.cmu.edu/~mgormley/courses/10423/)

10-425 Introduction to Convex Optimization

Intermittent: 12 units
As machine learning grows in prominence, so also has optimization become a mainstay for machine learning, particularly techniques for convex optimization. Most learning problems are formulated as optimization of some objective function, sometimes subject to constraints. This course explores the optimization algorithms used to solve these machine learning problems. We characterize the properties of the optimization problems that enable these techniques to be efficient (e.g. convexity, smoothness, linearity, separability) as well as properties that inhibit efficient optimization (e.g. nonconvexity). Core topics include first order methods (gradient descent, subgradient methods, proximal and stochastic gradient descent), duality and linear programming, and second-order/quasi-Newton methods. We also consider advanced techniques ranging from those that have spurred the growth of deep learning (e.g. adaptive gradient methods, momentum) and those that enable large-scale distributed optimization. The course will focus both on theory and practical applications, frequently drawing motivation from examples in machine learning. The course is designed so that a machine learning (ML) course could be taken after or before this one; ML is not a prerequisite. Students will gain the tools to both implement and analyze modern optimization techniques.
Prerequisites: (21-240 Min. grade C or 21-241 Min. grade C) and (21-325 Min. grade C or 36-219 Min. grade C or 36-217 Min. grade C or 15-359 Min. grade C) and (21-254 Min. grade C or 11-485 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C or 21-256 Min. grade C or 21-259 Min. grade C) and (15-151 Min. grade C or 21-127 Min. grade C) and 15-122 Min. grade C

Course Website: https://www.cs.cmu.edu/~mgormley/courses/10425 (https://www.cs.cmu.edu/~mgormley/courses/10425/)

10-500 Senior Research Project

All Semesters
Register for this course if you are minoring in Machine Learning. This course is intended for research with a faculty member that would count towards the minor.

10-520 Independent Study

All Semesters
Independent Study intended to work on research with a Machine Learning faculty member.

10-600 Mathematical background for Machine Learning

Fall and Spring: 12 units
This course provides a place for students to practice the necessary mathematical background for further study in machine learning and #8212; particularly for taking 10-601 and 10-701. Topics covered include probability, linear algebra (inner product spaces, linear operators), multivariate differential calculus, optimization, and likelihood functions. The course assumes some background in each of the above, but will review and give practice in each. (It does not provide from-scratch coverage of all of the above, which would be impossible in a course of this length.) Some coding will be required: the course will provide practice with translating the above mathematical concepts into concrete programs. This course supersedes the two mini-courses 10-606 and 10-607.

10-601 Introduction to Machine Learning (Master's)

Fall and Spring: 12 units
Machine Learning is concerned with computer programs that automatically improve their performance through experience (e.g., programs that learn to recognize human faces, recommend music and movies, and drive autonomous robots). This course covers the theory and practical algorithms for machine learning from a variety of perspectives. We cover topics such as decision tree learning, neural networks, statistical learning methods, unsupervised learning and reinforcement learning. The course covers theoretical concepts such as inductive bias, the PAC learning framework, Bayesian learning methods, and Occam's Razor. Programming assignments include hands-on experiments with various learning algorithms. This course is designed to give a graduate-level student a thorough grounding in the methodologies, technologies, mathematics and algorithms currently needed by people who do research in machine learning. 10-301 and 10-601 are identical. Undergraduates must register for 10-301 and graduate students must register for 10-601. 10-301 is recommended for undergraduates who are not SCS majors. (SCS majors should instead take 10-315.)
Prerequisites: 15-122 Min. grade C and (21-127 Min. grade C or 21-128 Min. grade C or 15-151 Min. grade C) and (36-219 Min. grade C or 36-218 Min. grade C or 36-217 Min. grade C or 15-259 Min. grade C or 36-220 Min. grade C or 36-235 Min. grade C or 21-325 Min. grade C or 15-359 Min. grade C or 36-225 Min. grade C)

Course Website: http://mlcourse.org

10-605 Machine Learning with Large Datasets

Fall and Spring: 12 units
Large datasets are difficult to work with for several reasons. They are difficult to visualize, and it is difficult to understand what sort of errors and biases are present in them. They are computationally expensive to process, and often the cost of learning is hard to predict - for instance, and algorithm that runs quickly in a dataset that fits in memory may be exorbitantly expensive when the dataset is too large for memory. Large datasets may also display qualitatively different behavior in terms of which learning methods produce the most accurate predictions. This course is intended to provide a student practical knowledge of, and experience with, the issues involving large datasets. Among the issues considered are: scalable learning techniques, such as streaming machine learning techniques; parallel infrastructures such as map-reduce; practical techniques for reducing the memory requirements for learning methods, such as feature hashing and Bloom filters; and techniques for analysis of programs in terms of memory, disk usage, and (for parallel methods) communication complexity. The class will include programming assignments, and a one-month short project chosen by the student. The project will be designed to compare the scalability of variant learning algorithms on datasets. An introductory course in machine learning, like 10-601 or 10-701, is a prerequisite or a co-requisite. If you plan to take this course and 10-601 concurrently please tell the instructor. The course will include several substantial programming assignments, so an additional prerequisite is 15-211, or 15-214, or comparable familiarity with Python and good programming skills.
Prerequisites: (15-211 or 17-214 or 15-210 or 15-214) and (10-601 or 10-401 or 10-715 or 10-701 or 10-301 or 10-315)

Course Website: https://10605.github.io/

10-606 Mathematical Foundations for Machine Learning

Fall: 6 units
This course provides a place for students to practice the necessary mathematical background for further study in machine learning. Topics covered include probability (random variables, modeling with continuous and discrete distributions), linear algebra (inner product spaces, linear operators), and multivariate differential calculus (partial derivatives, matrix differentials). The course assumes some background in each of the above, but will review and give practice in each. (It does not provide from-scratch coverage of all of the above, which would be impossible in a course of this length.) Some coding will be required: the course will provide practice with translating the above mathematical concepts into concrete programs. This course is one of two minis intended to prepare students for further study in machine learning and #8212; particularly for taking 10-601 and 10-701. One of the courses 10-606 focuses on mathematical background, and the other course 10-607 focuses on computational background. Most students take both mini courses, but this is not required. 10-606 is not a prerequisite of 10-607.

10-607 Computational Foundations for Machine Learning

Fall: 6 units
This course provides a place for students to practice the necessary computational background for further study in machine learning. Topics covered include computational complexity, analysis of algorithms, proof techniques, optimization, dynamic programming, recursion, and data structures. The course assumes some background in each of the above, but will review and give practice in each. (It does not provide from-scratch coverage of all of the above, which would be impossible in a course of this length.) Some coding will be required: the course will provide practice with translating the above computational concepts into concrete programs. This course is one of two minis intended to prepare students for further study in machine learning and #8212; particularly for taking 10-601 and 10-701. One of the courses 10-606 focuses on mathematical background, and the other course 10-607 focuses on computational background. Most students take both mini courses, but this is not required. 10-606 is not a prerequisite of 10-607.

10-608 Conversational Machine Learning

Intermittent: 12 units
Machine Learning today is largely about finding patterns in large amounts of data. But as personal devices that interact with us in natural language become ubiquitous (e.g., Siri, Google Now), they open an amazing possibility of letting users teach machines in natural language, similar to how we teach each other. Conversation, as an interface to machine learning systems, opens a new paradigm that both unifies several existing machine learning paradigms (e.g., active learning, supervised learning), but also brings a unique set of advantages and challenges that lie at the intersection of machine learning and natural language processing. This course will be structured as a well-defined mini-challenge (project) course. We will present you with several well-defined open problems and provide you with recently collected datasets that can get you started immediately! But you will be free to define your own problem using that data as well, or come up with your own problem entirely. There are no other constraints, and since this is a new area of research, you can (and should) be creative and as crazy in coming up with methods to tackle them. At the same time, we will provide guidance via readings and class-based hacking sessions. This course is a great way to get introduced to open problems in a collaborative and structured environment. Challenges Building a classifier with zero examples. Telling sequence to sequence models about their mistakes Letting machine learning models ask questions
Prerequisites: 10-715 Min. grade C or 10-601 Min. grade C or 10-401 Min. grade C or 10-701 Min. grade C

10-613 Machine Learning Ethics and Society

Intermittent: 12 units
The practice of Machine Learning (ML) increasingly involves making choices that impact real people and society at large. This course covers an array of ethical, societal, and policy considerations in applying ML tools to high-stakes domains, such as employment, education, lending, criminal justice, medicine, and beyond. We will discuss: (1) the pathways through which ML can lead to or amplify problematic decision-making practices (e.g., those exhibiting discrimination, inscrutability, invasion of privacy, and beyond); (2) recent technological methods and remedies to capture and alleviate these concerns; and (3) the scope of applicability and limitations of technological remedies in the context of several contemporary application domains. The course's primary goals are: (a) to raise awareness about the social, ethical, and policy implications of ML, and (b) to prepare students to critically analyze these issues as they emerge in the ever-expanding use of ML in socially consequential domains.
Prerequisites: 10-315 or 10-601 or 10-715 or 10-701 or 10-301

Course Website: http://www.cs.cmu.edu/~hheidari/mles-spring-23.html

10-617 Intermediate Deep Learning

Fall: 12 units
Building intelligent machines that are capable of extracting meaningful representations from data lies at the core of solving many AI related tasks. In the past decade, researchers across many communities, from applied statistics to engineering, computer science and neuroscience, have developed deep models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. The goal of this course is to introduce students to both the foundational ideas and the recent advances in deep learning. The first part of the course will focus on supervised learning, including neural networks, back-propagation algorithm, convolutional models, recurrent neural networks, and their extensions with applications to image recognition, video analysis, and language modelling. The second part of the course will cover unsupervised learning, including variational autoencoders, sparse-coding, Boltzmann machines, and generative adversarial networks. This course will assume a reasonable degree of mathematical maturity and will require strong programming skills.

Prerequisites: 10-601 Min. grade C or 10-701 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C or 10-715 Min. grade C

Course Website: https://deeplearning-cmu-10417.github.io

10-618 Machine Learning for Structured Data

Intermittent: 12 units
A key challenge in machine learning is that of structured prediction: taking unstructured data as input and producing a structured output. Structured prediction problems abound throughout application areas such as natural language processing, speech processing, computational biology, computer vision, healthcare, and many others. In this course, we will study modern approaches to structured prediction building on probabilistic graphical models, deep learning, and search. The course will focus on three key aspects: models, inference, and learning. The models we consider will focus on both generative and discriminative models such as Bayesian networks, Markov random fields (MRFs), conditional random fields (CRFs), and deep neural networks including convolutional neural networks (CNNs) and recurrent neural networks (RNNs) and #8212; as well as hybrids of graphical models and neural networks. The course will explore approaches to exact and approximate inference: junction tree algorithm, approximate marginal inference by Markov chain Monte Carlo (MCMC) and variational methods, approximate MAP inference by integer linear programming (ILP) and search. We will explore unsupervised, semi-supervised, and supervised learning using different formulations of the learning problem: MLE, Bayesian inference, structured perceptron, M3Ns, learning to search, and autoencoders. Covered applications will include machine translation, speech recognition, DNA sequence analysis, scene understanding, medical diagnosis. This course is cross-listed as 10-418 and 10-618; students registered for 10-618 will do a course project.
Prerequisites: 10-301 Min. grade C or 10-715 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C or 10-315 Min. grade C or 10-401 Min. grade C

10-623 Generative AI

Intermittent: 12 units
From generating images and text to generating music and art, the goal of generative modeling has long been a key challenge for artificial intelligence. This course explores the techniques from machine learning and artificial intelligence that are driving the recent advances in generative modeling and foundation models. Students will understand, develop, and apply state-of-the-art algorithms that enable machines to generate realistic and creative content. Core topics will include: the fundamental mechanisms of learning; how to build generative models and other large foundation models (e.g. transformers for vision and language, diffusion models); how to train such models (pre-training, fine-tuning) and efficiently adapt them (adapters, in-context learning); how to scale up to massive datasets (multi-GPU/distributed optimization); how to employ existing models for everyday use (generating code, coding with a generative model in the loop). Students will also explore the theoretical foundations and empirical attempts to understand their inner workings as well as learn about the ways in which things can go wrong (bias, hallucination, adversarial attacks, data contamination) and ways to combat these problems. Students in the course will develop understanding of modern techniques through implementation, but they will also employ existing libraries and models to explore their generative capabilities and limitations. The course is designed for students who have completed an introductory course in machine learning or deep learning.
Prerequisites: 10-301 Min. grade C or 11-785 Min. grade C or 11-685 Min. grade C or 11-485 Min. grade C or 10-715 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C or 10-315 Min. grade C

Course Website: https://www.cs.cmu.edu/~mgormley/courses/10423 (https://www.cs.cmu.edu/~mgormley/courses/10423/)

10-625 Introduction to Convex Optimization

Intermittent: 12 units
As machine learning grows in prominence, so also has optimization become a mainstay for machine learning, particularly techniques for convex optimization. Most learning problems are formulated as optimization of some objective function, sometimes subject to constraints. This course explores the optimization algorithms used to solve these machine learning problems. We characterize the properties of the optimization problems that enable these techniques to be efficient (e.g. convexity, smoothness, linearity, separability) as well as properties that inhibit efficient optimization (e.g. nonconvexity). Core topics include first order methods (gradient descent, subgradient methods, proximal and stochastic gradient descent), duality and linear programming, and second-order/quasi-Newton methods. We also consider advanced techniques ranging from those that have spurred the growth of deep learning (e.g. adaptive gradient methods, momentum) and those that enable large-scale distributed optimization. The course will focus both on theory and practical applications, frequently drawing motivation from examples in machine learning. The course is designed so that a machine learning (ML) course could be taken after or before this one; ML is not a prerequisite. Students will gain the tools to both implement and analyze modern optimization techniques.
Prerequisites: (21-240 Min. grade C or 21-241 Min. grade C) and (36-219 Min. grade C or 21-325 Min. grade C or 36-217 Min. grade C or 15-359 Min. grade C) and (10-315 Min. grade C or 21-259 Min. grade C or 10-301 Min. grade C or 21-256 Min. grade C or 21-254 Min. grade C or 11-485 Min. grade C) and (21-127 Min. grade C or 15-151 Min. grade C) and 15-122 Min. grade C

Course Website: https://www.cs.cmu.edu/~mgormley/courses/10425 (https://www.cs.cmu.edu/~mgormley/courses/10425/)

10-701 Introduction to Machine Learning

Fall and Spring: 12 units
Machine learning studies the question: "how can we build adaptive algorithms that automatically improve their performance (on a given task) as they acquire more experience?" This can cover a dizzying array of technologies depending on what sort of task we have in mind, and we take to constitute experience. Through this framing, we might view classical statistics problems, like estimating the likelihood that a coin lands on heads as an ML problem: the task is to produce an estimate, and the experience would consist of observations. But ML can also include robotics challenges, where the experience is acquired dynamically as our artificial agent interacts with the real world. Other grand challenges in machine learning relate to personalized medicine, natural language processing, and most recently generating media artifacts like photographs and essays (but don't ask chatGPT to do your homework). This course is designed to give PhD students a solid foundation in the methods, mathematics, and algorithms of modern machine learning. Students entering the class with a pre-existing working knowledge of probability, statistics and algorithms will be at an advantage, but the class has been designed so that anyone with a strong mathematical and computer science background can catch up and fully participate. If you are interested in this topic, but are not a PhD student, or are a PhD student not specializing in machine learning, you might consider the master's level course on Machine Learning, 10-601. This class may be appropriate for MS and undergrad students who are interested in the theory and algorithms behind ML.
Prerequisites: 15-122 Min. grade C and (21-128 Min. grade C or 15-151 Min. grade C or 21-127 Min. grade C) and (21-325 Min. grade C or 36-217 Min. grade C or 36-219 Min. grade C or 36-225 Min. grade C or 36-218 Min. grade C or 15-259 Min. grade C or 15-359 Min. grade C)

Course Website: https://machinelearningcmu.github.io/F23-10701/

10-702 Statistical Machine Learning

Spring: 12 units
Statistical Machine Learning is a second graduate level course in advanced machine learning, assuming that students have taken Machine Learning (10-701) or Advanced Machine Learning (10-715), and Intermediate Statistics (36-705). The term ?statistical? in the title reflects the emphasis on statistical theory and methodology. This course is mostly focused on methodology and theoretical foundations. It treats both the ?art? of designing good learning algorithms and the ?science? of analyzing an algorithm?s statistical properties and performance guarantees. Theorems are presented together with practical aspects of methodology and intuition to help students develop tools for selecting appropriate methods and approaches to problems in their own research. Though computation is certainly a critical component of what makes a method successful, it will not receive the same central focus as methodology and theory. We will cover topics in statistical theory that are important for researchers in machine learning, including consistency, minimax estimation, and concentration of measure. We will also cover statistical topics that may not be covered in as much depth in other machine learning courses, such as nonparametric density estimation, nonparametric regression, and Bayesian estimation.
Prerequisites: (10-705 or 36-705) and (10-701 or 10-715)

Course Website: http://www.stat.cmu.edu/~larry/=sml/

10-703 Deep Reinforcement Learning & Control

Spring: 12 units
This course will cover latest advances in Reinforcement Learning and Imitation learning. This is a fast developing research field and an official textbook is available only for about one fourth of the course material. The rest will be taught from recent research papers. This course brings together many disciplines of Artificial Intelligence to show how to develop intelligent agent that can learn to sense the world and learn to act imitating others or maximizing sparse rewards Particular focus will be given in incorporating visual sensory input and learning suitable visual state representations.
Prerequisites: 10-315 Min. grade B or 10-401 Min. grade B or 10-301 Min. grade B or 10-701 Min. grade B or 10-601 Min. grade B or 10-715 Min. grade B

Course Website: https://cmudeeprl.github.io/703website/

10-707 Advanced Deep Learning

Fall and Spring: 12 units
Models that are capable of extracting complex, hierarchical representations from high-dimensional data lie at the core of solving many ML and AI domains, such as visual object recognition, information retrieval, natural language processing, and speech perception. While the usefulness of such deep learning techniques is undisputed, our understanding of them is still in many ways nascent. The goal of this course is to introduce students to recent and exciting developments (both theoretical and practical) in these methods. This is an advanced graduate course, designed for Masters and Ph.D. level students, and will assume a substantial degree of mathematical maturity. Prerequisite: ML: 10-701 or 10-715, and strong programming skills.
Prerequisites: 10-715 Min. grade C or 10-401 Min. grade C or 10-315 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C

10-708 Probabilistic Graphical Models

Spring: 12 units
Many of the problems in artificial intelligence, statistics, computer systems, computer vision, natural language processing, and computational biology, among many other fields, can be viewed as the search for a coherent global conclusion from local information. The probabilistic graphical models framework provides an unified view for this wide range of problems, enabling efficient inference, decision-making and learning in problems with a very large number of attributes and huge datasets. This graduate-level course will provide you with a strong foundation for both applying graphical models to complex problems and for addressing core research topics in graphical models. The class will cover three aspects: The core representation, including Bayesian and Markov networks, and dynamic Bayesian networks; probabilistic inference algorithms, both exact and approximate; and, learning methods for both the parameters and the structure of graphical models. Students entering the class should have a pre-existing working knowledge of probability, statistics, and algorithms, though the class has been designed to allow students with a strong numerate background to catch up and fully participate. It is expected that after taking this class, the students should have obtain sufficient working knowledge of multi-variate probabilistic modeling and inference for practical applications, should be able to formulate and solve a wide range of problems in their own domain using GM, and can advance into more specialized technical literature by themselves. Students are required to have successfully completed 10701 or 10715, or an equivalent class.
Prerequisites: 10-701 Min. grade C or 10-601 Min. grade C or 10-301 Min. grade C or 10-315 Min. grade C or 10-715 Min. grade C

Course Website: https://andrejristeski.github.io/10708-22/

10-714 Deep Learning Systems: Algorithms and Implementation

Fall: 12 units
The goal of this course is to provide students an understanding and overview of the "full stack" of deep learning systems, ranging from the high-level modeling design of modern deep learning systems, to the basic implementation of automatic differentiation tools, to the underlying device-level implementation of efficient algorithms. Throughout the course, students will design and build from scratch a complete deep learning library, capable of efficient GPU-based operations, automatic differentiation of all implemented functions, and the necessary modules to support parameterized layers, loss functions, data loaders, and optimizers. Using these tools, students will then build several state-of-the-art modeling methods, including convolutional networks for image classification and segmentation, recurrent networks and self-attention models for sequential tasks such as language modeling, and generative models for image generation.
Prerequisites: (15-513 Min. grade C or 15-213 Min. grade C) and (21-240 Min. grade C or 21-241 Min. grade C) and (21-128 Min. grade C or 21-127 Min. grade C or 15-151 Min. grade C) and (10-315 Min. grade C or 10-601 Min. grade C or 10-701 Min. grade C or 10-715 Min. grade C or 10-301 Min. grade C)

10-715 Advanced Introduction to Machine Learning

Fall: 12 units
Machine Learning is the primary pillar that Artificial Intelligence is built upon. This course is designed for Ph.D. students whose primary field of study is machine learning, and who intend to make machine learning methodological research a main focus of their thesis. It will give students a thorough grounding in the algorithms, mathematics, theories, and insights needed to do in-depth research and applications in machine learning. The topics of this course will in part parallel those covered in the general PhD-level machine learning course (10-701), but with a greater emphasis on depth in theory. Students entering the class are expected to have a pre-existing strong working knowledge of linear algebra, probability, statistics, and algorithms. The course will also involve programming in Python. If you are interested in this topic, but do not have the required background or are not planning to work on a PhD thesis with machine learning as the main focus, you might consider the general PhD-level Machine Learning course (10-701) or the Masters-level Machine Learning course (10-601). You can find a webpage to the Intro to ML course comparison page, which includes a self-assessment exam to help you choose which Intro to ML course to take, in the Course URL field.
Prerequisites: 15-122 Min. grade C and (15-151 Min. grade C or 21-127 Min. grade C or 21-128 Min. grade C) and (15-359 Min. grade C or 36-225 Min. grade C or 36-217 Min. grade C or 21-325 Min. grade C or 15-259 Min. grade C or 36-218 Min. grade C)

Course Website: https://www.cs.cmu.edu/~nihars/teaching/10715-Fa23/index.html (https://www.cs.cmu.edu/~nihars/teaching/10715-Fa23/)

10-716 Advanced Machine Learning: Theory and Methods

Spring: 12 units
Advanced Machine Learning is a graduate level course introducing the theoretical foundations of modern machine learning, as well as advanced methods and frameworks used in modern machine learning. The course assumes that students have taken graduate level introductory courses in machine learning (Introduction to Machine Learning, 10-701 or 10-715), as well as Statistics (Intermediate Statistics, 36-700 or 36-705). The course treats both the art of designing good learning algorithms, as well as the science of analyzing an algorithm's computational and statistical properties and performance guarantees. Theorems are presented together with practical aspects of methodology and intuition to help students develop tools for selecting appropriate methods and approaches to problems in their own research. We will cover advanced machine learning methods such as nonparametric and deep compositional approaches to density estimation and regression; advanced theory such as fundamentals of clustering, classification, boosting; theory and methods at the intersection of statistical and computational efficiency; as well as vignettes of theoretical results on some hot topics such as robustness and explainability.
Prerequisites: (10-701 Min. grade C or 10-715 Min. grade C) and (36-705 Min. grade C or 36-700 Min. grade C)

Course Website: http://www.cs.cmu.edu/~pradeepr/716/

10-725 Convex Optimization

Intermittent: 12 units
Nearly every problem in machine learning can be formulated as the optimization of some function, possibly under some set of constraints. This universal reduction may seem to suggest that such optimization tasks are intractable. Fortunately, many real world problems have special structure, such as convexity, smoothness, separability, etc., which allow us to formulate optimization problems that can often be solved efficiently. This course is designed to give a graduate-level student a thorough grounding in the formulation of optimization problems that exploit such structure, and in efficient solution methods for these problems. The main focus is on the formulation and solution of convex optimization problems, though we will discuss some recent advances in nonconvex optimization. These general concepts will also be illustrated through applications in machine learning and statistics. Students entering the class should have a pre-existing working knowledge of algorithms, though the class has been designed to allow students with a strong numerate background to catch up and fully participate. Though not required, having taken 10-701 or an equivalent machine learning or statistical modeling class is strongly encouraged, as we will use applications in machine learning and statistics to demonstrate the concepts we cover in class. Students will work on an extensive optimization-based project throughout the semester.
Prerequisites: (21-240 Min. grade C or 10-606 Min. grade C or 21-671 Min. grade C or 21-242 Min. grade C or 21-341 Min. grade C) and (21-254 Min. grade C or 21-259 Min. grade C or 21-268 Min. grade C) and (15-259 Min. grade C or 36-218 Min. grade C or 36-219 Min. grade C or 36-225 Min. grade C or 21-325 Min. grade C or 15-359 Min. grade C or 36-217 Min. grade C)

Course Website: https://sites.google.com/view/convexopt-10725-2023f (https://sites.google.com/view/convexopt-10725-2023f/)

10-735 Responsible AI

Intermittent: 12 units
The development and deployment of artificial intelligence (AI) systems increasingly involves choices that impact people's lives and society at large. The responsible development and use of AI requires the integration of ethical, societal, and policy considerations into the use of AI tools and the development of AI systems in high-stakes domains, such as employment, education, lending, criminal justice, medicine, and beyond. We will discuss: (1) the pathways through which AI can lead to or amplify problematic decision-making practices (e.g., discrimination, inscrutability, invasion of privacy, and beyond); (2) recent technological methods and remedies to capture and alleviate these concerns; and (3) the scope of applicability and limitations of technological remedies in the context of several contemporary application domains. The course's primary goals are: (a) to raise awareness about the social, ethical, and policy implications of AI, and (b) to prepare students to critically analyze these issues as they emerge in the ever-expanding use of AI in socially consequential domains.
Prerequisites: 15-122 Min. grade C and (21-127 Min. grade C or 15-151 Min. grade C or 21-128 Min. grade C) and (36-217 Min. grade C or 21-325 Min. grade C or 36-218 Min. grade C or 36-219 Min. grade C or 15-259 Min. grade C or 36-235 Min. grade C or 36-225 Min. grade C or 15-359 Min. grade C)

Course Website: https://www.cs.cmu.edu/~hheidari/rai-spring-24.html

10-737 Creative AI

Intermittent
Artificial intelligence (AI) systems now generate authentic paintings, compose music pieces, and find out-of-box solutions to real-life problems in our world. Creativity, which was considered to be a moon shot for AI, does not seem to be too far any more. Is that true? Are we close to see creative AI? The answer is yes and no. We are moving closer with meaningful developments in Machine Learning, however there are several questions to be explored further to achieve the creative AI. What kind of creativity we want to represent? How do we translate creativity into what machines can understand? How do we design ML algorithms to be more creative? This course is where we explore these questions through seminars and projects. Our goal is to design computational models that present the very possibility of the creative AI. The instructors who are specialized in Machine Learning Art and Robotics lead this course together. We introduce related examples and possible methods including multi-modal data-driven learning, learning from demonstration, and combined learning from data and human demonstrations. Students are welcome to bring in their expertise and passion from diverse backgrounds to explore this topic together.

Course Website: http://kangeunsu.com/creativeai19f/

10-745 Scalability in Machine Learning

Fall: 12 units
The goal of this course is to provide a survey into some of the recent advances in the theory and practice of dealing with scalability issues in machine learning. We will investigate scalability issues along the following dimensions: Challenges with i) large datasets, ii) high-dimensions, and iii) complex data structure. The course is intended to prepare students to write research papers about scalability issues in machine learning. This is an advanced-level, fast-paced course that requires students to already have a solid understanding of machine learning (e.g. by taking an intro to ML class), good programming skills in Python, and being comfortable with dealing with abstract mathematical concepts and reading research papers. The course will have significant overlap with 10-405/605/805, but 10-745 will be faster-paced and go deeper into the theoretical investigations of the methods. Some of the classes will be flipped that will require students to watch a video lecture or read a research paper before the class, and the content will be discussed during the class time. The class will include a course project, HW assignments, and two-in class exams.
Prerequisites: 10-601 Min. grade B or 10-315 Min. grade B or 10-701 Min. grade B or 10-401 Min. grade B or 10-301 Min. grade B or 10-715 Min. grade B

10-777 Historical Advances in Machine Learning

Intermittent: 12 units
We will read (before class) and discuss (in class) a variety of historically important papers in ML (and to some extent AI). Not all of these were initially published in the ML/AI literature (eg: Bellman in math, VC in probability, bandits in statistics, fuzzy sets in control, optimization work in OR, etc, but now play central roles in ML and/or AI). Since "historical" is always ambiguous, we're going to go with "presented/published before the instructor was born" as a definition (pre-1988). While the content of the paper will be the primary focus, we will also attempt to understand the research context in which the paper was written. For example, what questions were other researchers asking at the time? Was the paper immediately recognized as a breakthrough or did it take a long time? Do we view the contents of the paper today as "obvious in hindsight" or is there still a lot of material in the paper that is nontrivial and even surprising or underappreciated? Who was the author, were they already relatively well known when they wrote the paper, or was it the paper itself that made them famous? What else did these authors work on before/after the paper?
Prerequisites: 10-601 Min. grade C or 10-701 Min. grade C or 10-715 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C

10-805 Machine Learning with Large Datasets

Spring: 12 units
Large datasets pose difficulties across the machine learning pipeline. They are difficult to visualize and introduce computational, storage, and communication bottlenecks during data preprocessing and model training. Moreover, high capacity models often used in conjunction with large datasets introduce additional computational and storage hurdles during model training and inference. This course is intended to provide a student with the mathematical, algorithmic, and practical knowledge of issues involving learning with large datasets. Among the topics considered are: data cleaning, visualization, and pre-processing at scale; principles of parallel and distributed computing for machine learning; techniques for scalable deep learning; analysis of programs in terms of memory, computation, and (for parallel methods) communication complexity; and methods for low-latency inference. The class will include programming and written assignments to provide hands-on experience applying machine learning at scale. An introductory machine learning course (10-301, 10-315, 10-601, 10-701, or 10-715) is a prerequisite. A strong background in programming will also be necessary; suggested prerequisites include 15-210, 15-214, or equivalent. Students are expected to be familiar with Python or learn it during the course.
Prerequisites: (17-214 or 15-211 or 15-210 or 15-214) and (10-301 or 10-315 or 10-701 or 10-401 or 10-601 or 10-715)

Course Website: https://10605.github.io/

10-806 Foundations of Machine Learning and Data Science

Fall: 12 units
This course will cover fundamental topics in Machine Learning and Data Science, including powerful algorithms with provable guarantees for making sense of and generalizing from large amounts of data. The course will start by providing a basic arsenal of useful statistical and computational tools, including generalization guarantees, core algorithmic methods, and fundamental analysis models. We will examine questions such as: Under what conditions can we hope to meaningfully generalize from limited data? How can we best combine different kinds of information such as labeled and unlabeled data, leverage multiple related learning tasks, or leverage multiple types of features? What can we prove about methods for summarizing and making sense of massive datasets, especially under limited memory? We will also examine other important constraints and resources in data science including privacy, communication, and taking advantage of limited interaction. In addressing these and related questions we will make connections to statistics, algorithms, linear algebra, complexity theory, information theory, optimization, game theory, and empirical machine learning research. Topics to be covered will include:
- Fundamental measures of complexity for generalization, including VC-dimension and Rademacher complexity. - Core algorithmic tools including boosting, regularization, and online optimization with connections to game theory. - Spectral methods, streaming algorithms and other approaches for handling massive data. - Foundations and algorithms for addressing important constraints or externalities such as privacy, limited memory, and communication constraints. - Foundations for modern learning paradigms including semi-supervised learning, never-ending learning, interactive learning, and deep learning.

Course Website: http://www.cs.cmu.edu/~ninamf/courses/806/10-806-index.html (http://www.cs.cmu.edu/~ninamf/courses/806/10-806-)

10-807 Topics in Deep Learning

Fall: 12 units
Building intelligent machines that are capable of extracting meaningful representations from high-dimensional data lies at the core of solving many AI related tasks. In the past few years, researchers across many different communities, from applied statistics to engineering, computer science and neuroscience, have developed deep (hierarchical) models and #8212; models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. This is an advanced graduate course, designed for Master's and Ph.D. level students, and will assume a reasonable degree of mathematical maturity. The goal of this course is to introduce students to the recent and exciting developments of various deep learning methods. Some topics to be covered include: restricted Boltzmann machines (RBMs) and their multi-layer extensions Deep Belief Networks and Deep Boltzmann machines; sparse coding, autoencoders, variational autoencoders, convolutional neural networks, recurrent neural networks, generative adversarial networks, and attention-based models with applications in vision, NLP, and multimodal learning. We will also address mathematical issues, focusing on efficient large-scale optimization methods for inference and learning, as well as training density models with intractable partition functions. Prerequisite: ML: 10-701 or 10-715, and strong programming skills.
Prerequisites: 10-715 Min. grade C or 10-701 Min. grade C

10-822 Presentation Skills

Fall and Spring: 6 units
This course provides a forum for students to learn and refine public speaking and technical reading skills. The course will include brief workshops embedded throughout the semester to cover such things as effective structure of presentations and papers, how to give a short talk (think NIPS spotlights), "elevator" talks, structure of a research paper, conference presentations, proposal writing (think thesis and beyond), slide crafting, posters, critical evaluation, and public communications for research. Students will be expected to prepare and present a number of practice talks throughout the semester.

10-830 Machine Learning in Policy

Spring: 12 units
Machine learning, a field derived primarily from computer science and statistics, has matured and gained wide adoption over past decades. Alongside exponential increases in data measurement and availability, the ability to develop appropriate and tailored analyses is in demand. As practitioners in the social sciences consider machine learning methods, however, we are identifying limitations and externalities of the applications of machine learning techniques, such as overconfidence in settings with concept drift, lack of generalizability due to selection bias, and magnification of inequities. Machine Learning and Policy seeks to (1) demonstrate motivations and successes of machine learning, to (2) contrast them with more classical methods, and to (3) investigate the promise and cautions of machine learning for public policy. The course will cover variety of topics, including: Basics of machine learning; probability/Bayes/likelihood/conjugacy, terminology, code/algorithm design, evaluation, mathematical formulations Popular and well-performing methods; random forests/trees/ensembles, neural networks/backpropagation/embeddings/generalized adversarial networks, generalized linear models/shrinkage/convexity/basis functions, support vector machines/kernels/optimization/Lagrangian Leveraging other data sources; natural language processing/topic modeling/relational (non-i.i.d.)/relational (Markov logic networks)/temporal data Additional topics: causality/confounding/propensity scoring/inverse weighting/causal directed acyclic graphs, fairness/ethics, interpretation/explanation/visualization, anomaly detection, semi-supervised and active learning, reinforcement learning.

Course Website: https://www.andrew.cmu.edu/user/jweiss2/mlp/

10-831 Special Topics in Machine Learning and Policy

Spring: 6 units
Special Topics in Machine Learning and Policy (90-921/10-831) is intended for Ph.D. students in Heinz College, MLD, and other university departments who wish to engage in detailed exploration of a specific topic at the intersection of machine learning and public policy. Qualified master's students may also enroll with permission of the instructor; all students are expected to have some prior background in machine learning and data mining (10-601, 10-701, 90-866, 90-904/10-830, or a similar course). We will explore state-of-the-art methods for detection of emerging events and other relevant patterns in massive, high-dimensional datasets, and discuss how such methods can be applied usefully for the public good in medicine, public health, law enforcement, security, and other domains. The course will consist of lectures, discussions on current research articles and future directions, and course projects. Specific topics to be covered may include: anomaly detection, change-point detection, time series monitoring, spatial and space-time scan statistics, pattern detection in graph data, submodularity and LTSS properties for efficient pattern detection, combining multiple data sources, scaling up pattern detection to massive datasets, applications to public health, law enforcement, homeland security, and health care. A sample syllabus is available at: http://www.cs.cmu.edu/~neill/courses/90921-S10.html
Course Website: http://www.cs.cmu.edu/~neill/courses/90921-S10.html

Robotics Courses

16-161 ROB Seminar: Artificial Intelligence and Humanity

Fall and Spring: 12 units
In 1965 British mathematician I.J. Good wrote, An ultraintelligent machine could design even better machines; there would then unquestionably be an intelligence explosion, and the intelligence of man would be left far behind. As we enter an age where companies like Uber are testing driverless cars in Pittsburgh and innovative interfaces like IBMs Watson can play jeopardy and learn techniques for medical diagnoses, how are we to negotiate an intelligence explosion that for many individuals might threaten the very notions of what it means to be human? The future of human-to-machine relationships will likely define our historical epoch and yet, many young technologists and humanists underestimate the downstream impact of technological innovations on human society. Presently, we have little choice but to attend to this rapidly anxiety-ridden question. This seminar will attend to the challenge of present existential questions on what it means to be human (read not machine) in the context of a rapidly advancing technological age. We will consider human narratives throughout history that exam how governments and individual citizens defined humanity in the context of slavery and colonialism as a framework for exploring and projecting what it means to be human in the age of rapidly advancing intelligent machines. We will trace the technological advancements of the recent five decades and identify historical precedents and speculative narratives that help us to consider issues like labor, economic disparity, negotiations of power, human dignity and ethical responsibility within the context of human relations with advancing technological tools that are now coined, artificial intelligence.

16-170 Concepts of Robotics

Spring: 5 units
The course will introduce students to the main foundational concepts and techniques used in robotics including perception, cognition, and action. Concepts will be grounded in a range of real-world robotic systems to highlight the use of common robotics components such as sensor selection, sensor processing and fusion, path planning algorithms, mechanism design, reasoning about interactions with the environment, and systems integration. Applications of robotics will be discussed along with methods for mapping application requirements to design choices for robotic systems. Students will also be introduced to ethical issues surrounding robotics, including considerations around potential future of uses of robotics technologies. The course will contain programming and written assignments designed to give students a feel for the practical aspects of robot sensing, planning, and actuation.
Prerequisite: 15-112 Min. grade C

16-211 Foundational Mathematics of Robotics

Fall: 12 units
This course will cover core mathematics concepts used in many advanced robotics courses at the RI. Perhaps unlike prior courses in math, the focus of this class will be to ground concepts in robotics algorithms or applications. For example: How to move and manipulate objects in 3D space (coordinate transforms, rotations). How to move an articulated robots end-effector in Cartesian space (Jacobians, gradient optimization). How to have a robot learn to recognize a vision input (neural networks, back propagation). How to plan navigate a robot optimally (dynamic programming, A* Search).
Prerequisites: 21-122 and 21-241

16-220 Robot Building Practices

Fall: 12 units
This course is designed to provide students with a comprehensive set of mechanical and electronics skills required for designing, prototyping, building, and troubleshooting robotic systems. Students will learn about basic robotic components and how to obtain, build, or fix them to create functional robotic systems. The course will cover mechanical skills specific to robotics, including sketching, 3D CAD modeling, 3D printing, laser cutting and other machine shop tools. Students will also learn the fundamentals of circuit design, breadboarding, and PCB layout using CAD tools, as well as how to use measurement equipment and soldering techniques. They will gain hands-on experience with motor controllers and microcontrollers, essential components for controlling robots. The class project will give students the opportunity to learn how to design and implement power transmission systems and prototype mechanical components required in building a functional robotic module and later a full robotic system. The course will include robot-specific topics such as kinematics, robot actuators, sensors, and perception algorithms. Upon completion of this course, students will have a solid foundation in electronics and mechanical prototyping for robotics and be able to create innovative robots for a variety of applications.
Prerequisite: 15-122 Min. grade C

16-223 IDeATe Portal: Creative Kinetic Systems

Fall: 10 units
The art and science of machines which evoke human delight through physical movement is founded on a balance of form and computation. This introductory physical computing course addresses the practical design and fabrication of robots, interactive gadgets, and kinetic sculptures. The emphasis is on creating experiences for human audiences through the physical behavior of devices which embody computation with mechanism, sensing, and actuation. Specific topics include basic electronics, elementary mechanical design, embedded programming, and parametric CAD. A key objective is gaining an intuitive understanding of how information and energy move between the physical, electronic, and computational domains to create a compelling behavior. The final projects are tested in the field on children and adults. This interdisciplinary course is an IDeATe Portal Course open to students from all colleges. For students choosing to follow an IDeATe program it is an entry into either Physical Computing or Intelligent Environments. The structure of the class revolves around collaborative exercises and projects which introduce core physical computing and system engineering techniques in a human-centric context. Students apply system and design thinking across multiple domains, work together to make and test several devices, and participate in wide-ranging critique which considers both technical and artistic success.

Course Website: https://courses.ideate.cmu.edu/16-223 (https://courses.ideate.cmu.edu/16-223/)

16-224 IDeATe: Re-Crafting Computational Thinking with Soft Technologies

Spring: 12 units
This course focuses on teaching introductory concepts of Robotics, Mechatronics, and Computer Science using an arts-based approach. During the course, students will build their own weaving robot, program it, and learn how weaving art is connected to computer programming and matrix mathematics. Students will also learn the history of weaving, how to design beautiful patterns, and how to extract the features of those patterns into mathematical equations and computer programs.

16-235 Fantastic Robots and How to Fold Them

Spring: 9 units
This course will focus on the basics of robotics through a hands-on approach. Students will build their own robots by designing a mechanical structure and embedding actuators, sensors, and controllers. They will then use these robots to solve a simple maze with obstacles. The course content will be delivered through lectures, workshops, and a course-long team project. In classical robotics, we explore the three main behaviors of robots through the work frame of "sense-plan-act". Robots are more than just these behaviors, and students will learn about how to make the physical embodiments of robots through an overview of design and manufacturing techniques for robot mechanisms. Students will be able to make their own mechanisms, improve the system through hardware or software, and learn how to analyze the kinematics and dynamics of these mechanisms to understand and control the motion.
Prerequisites: 15-110 Min. grade C or 15-112 Min. grade C or 15-104 Min. grade C

16-264 Humanoids

Spring: 12 units
This course surveys perception, cognition, and movement in humans, humanoid robots, and humanoid graphical characters. Application areas include more human-like robots, video game characters, and interactive movie characters.

Course Website: http://www.cs.cmu.edu/~cga/humanoids-ugrad/

16-299 Introduction to Feedback Control Systems

Spring: 12 units
This course is designed as a first course in feedback control systems for computer science majors. Course topics include classical linear control theory (differential equations, Laplace transforms, feedback control), linear state-space methods (controllability/observability, pole placement, LQR), nonlinear systems theory, and an introduction to control using computer learning techniques. Priorities will be given to computer science majors with a robotics major or minor.
Prerequisites: 21-122 and 15-122

Course Website: http://www.cs.cmu.edu/~cga/controls-intro/

16-311 Introduction to Robotics

Spring: 12 units
This course presents an overview of robotics in practice and research with topics including vision, machine learning, motion planning, mobile mechanisms, kinematics, inverse kinematics, and sensors. In course projects, students construct LEGO robots which are driven by a microcontroller, with each project reinforcing the basic principles developed in lectures. Students usually work in teams of three: an electrical engineer, a mechanical engineer, and a computer scientist. Groups are typically self-formed except for the first lab. This course will also expose students to some of the contemporary happenings in robotics, including current robotics research, applications, robot contests and robots in the news. Students registering for this course must register for both Mon/Wed mornings and Tuesday afternoon sections.
Prerequisites: 18-202 Min. grade C or 21-240 Min. grade C or 21-241 Min. grade C or 24-311 Min. grade C or 21-260 Min. grade C

Course Website: http://www.cs.cmu.edu/afs/cs.cmu.edu/academic/class/16311/www/current/

16-322 Modern Sensors for Intelligent Systems

Spring: 12 units
The class aims at introducing sensing technologies for robots and other intelligent systems. The course will cover the physical principles of traditional sensors, sensor calibration and evaluation, signal processing algorithms for different sensors, and examples of sensor applications for robots or other intelligent systems. On the sensing system design part, the course will cover the common sensor fusion design and algorithms, and provide examples of sensing systems for different robots or intelligent systems, such as wearable sensors, self-driving cars, autonomous vehicles, assistant robots, and field robots in extreme conditions. The class will contain lectures, two lab sessions, and a course project.

16-350 Planning Techniques for Robotics

Spring: 12 units
Planning is one of the core components that enable robots to be autonomous. Robot planning is responsible for deciding in real-time what should the robot do next, how to do it, where should the robot move next and how to move there. This class does an in-depth study of popular planning techniques in robotics and examines their use in ground and aerial robots, humanoids, mobile manipulation platforms and multi-robot systems. The students learn the theory of these methods and also implement them in a series of programming-based projects. To take the class students should have taken an Intro to Robotics class and have a good knowledge of programming and data structures.

Course Website: http://www.cs.cmu.edu/~maxim/classes/robotplanning/

16-362 Mobile Robot Algorithms Laboratory

Fall: 12 units
This course is an introduction to the theory and algorithms of multirotor vehicle autonomy. Students will work individually to develop a multirotor simulator in Python and C++, add sensors, plan, and perform exploration. Lectures will cover topics to advance the capabilities of the simulator. Homeworks will be designed to increase the autonomy capabilities of the multirotor vehicle. The class will culminate in an individual project that pushes the autonomy capabilities developed throughout the course and may cover multi-robot aerial autonomy, dynamic environment modeling, or advanced planning and control. In order to succeed in the course, students must have a 2nd year science/engineering level background in mathematics (matrices, vectors, coordinate systems) and have already mastered at least one object-oriented programming language like C++ or Python. When the course is over, students will have written a single software system that has been incrementally extended in functionality and regularly debugged throughout the semester.

16-371 Personalized Responsive Environments

Spring: 9 units
[IDeATe collaborative course]. Environmental factors have a significant impact on mood and productivity. Creating responsive environments necessitates the design of surroundings that are able to metamorphose in order to optimize user strengths and available resources and evolve in stride with user needs. This course will investigate the development of spaces that adapt to user preferences, moods, and task specific demands. Both the design and engineering of such personalized environments will be explored. Central course concepts will include, understanding the user, integrating various modalities (e.g., light, heat, sound) to support the changing needs of task and user, and the creation of adaptive environments that learn user preferences over time. Please note that there may be usage/materials fees associated with this course.
Prerequisites: 60-223 Min. grade C or 62-150 Min. grade C or 18-090 Min. grade C or 15-104 Min. grade C

16-374 IDeATe: Art of Robotic Special Effects

Spring: 12 units
Inspired by the early "trick" films of George Melies, this project-oriented course brings together robotics and film production technique to infuse cinema with the wonder of live magic. Students will learn the basics of film production using animatronics, camera motion control, and compositing. The projects apply these techniques to create innovative physical effects for short films, all the way from concept to post-production. The course emphasizes real-time practical effects to explore the immediacy and interactivity of improvisation and rehearsal. The robotics topics include animatronic rapid prototyping and programming human-robot collaborative performance. The course includes a brief overview of the history of special effects and robotics to set the work in context.

Course Website: https://courses.ideate.cmu.edu/16-374 (https://courses.ideate.cmu.edu/16-374/)

16-375 IDeATe: Robotics for Creative Practice

Fall: 10 units
Robots come in all shapes and sizes: it is the integration of software and hardware that can make any machine surprisingly animate. This project-oriented course brings art and engineering together to build performance systems using embodied behavior as a creative medium. Students learn skills for designing, constructing and programming automated systems for storytelling and human interaction, then explore the results through exhibition and performance. Technical topics include closed-loop motion control, expressive physical and computational behavior, machine choreography, and performance conceptualization. Discussion topics include both contemporary kinetic sculpture and robotics research. This interdisciplinary course is part of IDeATe Physical Computing but is open to any student.
Prerequisites: 15-110 or 15-104 or 15-112 or 99-361 or 60-212 or 60-210

Course Website: https://courses.ideate.cmu.edu/16-375 (https://courses.ideate.cmu.edu/16-375/)

16-376 IDeATe: Kinetic Fabrics

Spring: 10 units
Kinetic Fabrics brings together the fields of robotics and textiles to explore their unified creative and expressive potential. It is a wide-open frontier for kinetic art, wearable art, and architectural installation. In this course students will build a variety of performative systems combining fabrics and robotic technologies. Students will apply modular actuation and sensing to textile artworks, using software designed to facilitate fluid explorations, rapid iterations, and playful experimentation. Students will learn basic textile skills, such as hand and machine sewing, as well as gain facility and familiarity with the characteristics of multiple type of fabrics. Historical precedents as well as contemporary examples of works will support students creative growth and knowledge of the field. Students' course work will include short-term and long-term projects, sampling and prototyping, critique, and documentation. Additionally, students will organize an end-of-semester event where they will perform a developed kinetic fabric work for a public audience.

Course Website: https://courses.ideate.cmu.edu/16-376 (https://courses.ideate.cmu.edu/16-376/)

16-384 Robot Kinematics and Dynamics

Fall: 12 units
Foundations and principles of robotic kinematics. Topics include transformations, forward kinematics, inverse kinematics, differential kinematics (Jacobians), manipulability, and basic equations of motion. Course also include programming on robot arms.
Prerequisites: 15-122 Min. grade C or 16-311 or 18-202 or 21-241 or 24-311

16-385 Computer Vision

Fall and Spring: 12 units
This course provides a comprehensive introduction to computer vision. Major topics include image processing, detection and recognition, geometry-based and physics-based vision, sensing and perception, and video analysis. Students will learn basic concepts of computer vision as well as hands on experience to solve real-life vision problems. This course is for undergraduate students only.
Prerequisites: (18-202 Min. grade C and 15-122 Min. grade C) or (21-259 Min. grade C and 15-122 Min. grade C and 21-241 Min. grade C) or (21-241 Min. grade C and 21-256 Min. grade C and 15-122 Min. grade C) or (24-282 Min. grade C and 15-122 Min. grade C and 21-241 Min. grade C) or (21-254 Min. grade C and 15-122 Min. grade C and 21-241 Min. grade C)

Course Website: http://www.cs.cmu.edu/~16385/

16-397 Art, Conflict and Technology

Spring: 12 units
This course considers the period of violence in Northern Ireland from 1968 to 1998 known as The Troubles, and recent issues pertaining to sovereignty and borders caused by Brexit, Britain's proposed exit from the European Union, as a point of comparison between societies rife with strife, division and predilections to violence. We investigate the ways in which visual art to literature to theatrical performance explores and interrogates societal conflict and emergence from conflict, and how evolving technological systems influence political power dynamics and modes of artistic practice. We will use the legacy of societal conflict in Ireland and Northern Ireland to compare concepts and physical manifestations of borders, barriers and bridges in the region and in global contexts. We will examine fluctuating development of democratic processes in Ireland and Northern Ireland, individual and group public performance, and the influence of technologically crude and highly sophisticated tools on communities emerging from strife. We will use our analytical lens to focus on figurative and literal borders, barriers and bridges to explore work produced in Belfast, Derry and Dublin, alongside circumstances and artistic practice in present-day Pittsburgh, Cuidad Juarez, Jerusalem and Soweto. On a visit to Ireland and Northern Ireland over spring break, students will meet with artists, writers, legislators, community organizers, academics and ex-combatants, to learn about their past experience and current motivations. Students will analyze artistic practice, peacekeeping initiatives and performance of identity in relation to the historical framework from which it emerges in Ireland and Northern Ireland. We will use this foundation as a point of comparison to practices throughout the world. Students will process their experience and developing analytical skills by documenting their responses through original creative work.

16-421 Vision Sensors

Spring: 12 units
This course covers the fundamentals of vision cameras and other sensors - how they function, how they are built, and how to use them effectively. The course presents a journey through the fascinating five hundered year history of "camera-making" from the early 1500's "camera obscura" through the advent of film and lenses, to today's mirror-based and solid state devices (CCD, CMOS). The course includes a significant hands-on component where students learn how to use the sensors and understand, model and deal with the uncertainty (noise) in their measurements. While the first half of the course deals with conventional "single viewpoint" or "perspective" cameras, the second half of the course covers much more recent "multi-viewpoint" or "multi-perspective" cameras that includes a host of lenses and mirrors.
Prerequisites: 21-111 and 21-241

Course Website: http://www.cs.cmu.edu/~ILIM/courses/vision-sensors/

16-423 Designing Computer Vision Apps

Fall: 12 units
Computer vision is a discipline that attempts to extract information from images and videos. Nearly every smart device on the planet has a camera, and people are increasingly interested in how to develop apps that use computer vision to perform an ever expanding list of things including: 3D mapping, photo/image search, people/object tracking, augmented reality etc. This course is intended for students who are not familiar with computer vision, but want to come up to speed rapidly with the latest in environments, software tools and best practices for developing computer vision apps. No prior knowledge of computer vision or machine learning is required although a strong programming background is a must (at a minimum good knowledge of C/C++). Topics will include using conventional computer vision software tools (OpenCV, MATLAB toolboxes, VLFeat, CAFFE), and development on iOS devices using mobile vision libraries such as GPUImage and fast math libraries like Armadillo and Eigen. For consistency, all app development will be in iOS and it is expected that all students participating in the class have access to an Intel-based MAC running OS X Mavericks or later. Although the coursework will be focussed on a single operating system, the knowledge gained from this class is intended to generalize to other mobile platforms such as Android etc.
Prerequisites: (21-240 and 15-213) or (21-241 and 15-213) or (18-202 and 18-213)

Course Website: http://16423.courses.cs.cmu.edu

16-425 Medical Image Analysis

Spring: 12 units
Students will gain theoretical and practical skills in 2D, 3D, and 4D biomedical image analysis, including skills relevant to general image analysis. The fundamentals of computational medical image analysis will be explored, leading to current research in applying geometry and statistics to segmentation, registration, visualization, and image understanding. Additional and related covered topics include de-noising/restoration, morphology, level sets, and shape/feature analysis. Students will develop practical experience through projects using the latest version of the National Library of Medicine Insight Toolkit (ITK) and SimpleITK, a popular open-source software library developed by a consortium of institutions including Carnegie Mellon University and the University of Pittsburgh. In addition to image analysis, the course will include interaction with radiologists and pathologist(s). *** Lectures are at CMU and students will visit clinicians at UPMC. Some or all of the class lectures may also be videoed for public distribution, but students may request to be excluded from distributed video. 16-725 is a graduate class, and 16-425 is a cross-listed undergraduate section. 16-425 is new this year, and has substantially reduced requirements for the final project and for the larger homework assignments, nor does it require shadowing the clinicians. Prerequisites: Knowledge of vector calculus, basic probability, and either C++ or python, including basic command-line familiarity and how to pass arguments to your own command-line programs. Extensive expertise with C++ and templates is not necessary, but some students may find it helpful.

Course Website: http://www.cs.cmu.edu/~galeotti/methods_course/

16-441 Advanced CP/SIS: Urban Intervention

Fall and Spring: 12 units
This course introduces students to theories, practices, and communities for critical investigation of urban spaces and play within them. The course unfolds along two parallel trajectories: research (literature review, lectures, readings, demonstrations) and design (three iterated individualized projects and a fourth larger scale final project). The first half of the course will introduce students to a wide range of theories and techniques within urban intervention that draw from fluxus, the situationist international, activism and hacktivism, as well as public policy, philosophy, psychology and economics. Students will study theoretical and practical frameworks for artistic intervention into public urban spaces, while concurrently researching actual sites and communities within Pittsburgh for experimentation. Students are required to conceptualized projects on larger (urban) scales, and find ways to implement their projects safely and legally by pursuing the necessary administrative, social, technical, financial steps required to create meaningful interventions in public spaces. This class will specifically explore three media for urban intervention: Sound Outdoor video projection Robotics, Autonomy and Mobility in the way of remote control vehicles (e.g. cars, quad-copters, etc.). For each theme, students are required to produce one project that is iterated twice or more. The undergraduate (60441) and graduate (60741) sections of the course meet concurrently and follow the same syllabus and assignments. In addition to the coursework documented in the syllabus, Graduate level students are expected to write a research paper suitable for submission to a notable relevant academic conference. This process includes a rough draft, revisions and a completed and formatted paper ready for submission

16-450 Robotics Systems Engineering

Fall: 12 units
Systems engineering examines methods of specifying, designing, analyzing and testing complex systems. In this course, principles and processes of systems engineering are introduced and applied to the development of robotic devices. The focus is on robotic system engineered to perform complex behavior. Such systems embed computing elements, integrate sensors and actuators, operate in a reliable and robust fashion, and demand rigorous engineering from conception through production. The course is organized as a progression through the systems engineering process of conceptualization, specification, design, and prototyping with consideration of verification and validation. Students completing this course will engineer a robotic system through its compete design and initial prototype. The project concept and teams can continue into the Spring-semester (16-474 Robotics Capstone) for system refinement, testing and demonstration.
Prerequisites: 16-311 Min. grade B and (16-299 Min. grade B or 18-370 Min. grade B or 24-451 Min. grade B)

16-455 IDeATe: Human-Machine Virtuosity

Spring: 12 units
[IDeATe course] Human dexterous skill embodies a wealth of physical understanding which complements computer-based design and machine fabrication. This project-oriented course explores the duality between hand and machine through the practical development of innovative design and fabrication systems. These systems fluidly combine the expressivity and intuition of physical tools with the scalability and precision of the digital realm. Students will develop novel hybrid design and production workflows combining analog and digital processes to support the design and fabrication of their chosen projects. Specific skills covered include 3D modeling (CAD), 3D scanning, algorithmic geometric modeling, digital and robotic fabrication (additive and subtractive manufacturing), motion capture and computer based sensing, and human-robot interaction design. Areas of interest include architecture, art, and product design.

Course Website: https://courses.ideate.cmu.edu/16-455 (https://courses.ideate.cmu.edu/16-455/)

16-456 Reality Computing Studio

Fall: 12 units
[IDeATe collaborative course] Reality computing encompasses a constellation of technologies focused around capturing reality (laser scanning, photogrammetry), working with spatial data (CAD, physical modeling, simulation), and using data to interact with and influence the physical world (augmented / virtual reality, projector systems, 3d printing, robotics). Taught in collaboration with the school of architecture, this studio asks students to apply these technologies to real world problems such as residential design, sustainability, and infrastructure monitoring.

Course Website: http://ideate.cmu.edu/about-ideate/departments/robotics-institute/reality-computing/

16-457 Reality Computing II

Spring: 12 units
[IDeATe collaborative course] Reality computing encompasses a constellation of technologies focused around capturing reality (laser scanning, photogrammetry), working with spatial data (CAD, physical modeling, simulation), and using data to interact with and influence the physical world (augmented / virtual reality, projector systems, 3d printing, robotics). This iteration of the reality computing course will focus on "design realization": the translation from digital design to fully realized tangible artifact. Collaborating with the UDBS design studio, and within the context of a full-scale residential prototype, students will investigate how reality computing technologies can be used to accelerate and advance the process of design realization by using reality computing to understand existing homes, map design data into the real world, and highlight conflicts between design and reality. Topics of special focus within the course are residential design (John Folan) and augmented reality and robotics (Pyry Matikainen).

Course Website: http://ideate.cmu.edu/about-ideate/departments/robotics-institute/reality-computing/

16-461 Experimental Capture

Fall: 9 units
Performance capture is used in applications as varied as special effects in movies, animation, sports training, physical rehabilitation, and human-robot/human-computer interaction. This course will survey state-of-the-art techniques and emerging ideas, in the industry and in academia, to capture, model, and render human performances. The course will be a mix between lectures and discussion of recent progress in human motion capture and analysis. The course evaluation will be project-based, in which students will capture their own body and face motion, and build projects around the data they collect individually and as a group. We will cover: 1. Capture Techniques: We will describe and use various systems including motion capture, video-based capture, depth sensors, scanners, and eye-gaze trackers; 2. Modeling and Representation: We will cover classic and contemporary representations of face and body pose and motion, including statistical and physics-based techniques; 3. Rendering Applications: As new rendering paradigms emerge, new applications continue to develop. We will study recent progress in animation, synthesis, classification, and rehabilitation on new forms of displays. Please note that there may be usage/materials fees associated with this course.
Prerequisites: 60-422 or 15-365

16-465 Game Engine Programming

Spring: 10 units
This course is designed to help students understand, modify, and develop game engines. Game engines consist of reusable runtime and asset pipeline code. They provide game-relevant abstractions of low-level system services and libraries, making it easier to write bug-free games that work across multiple platforms. Game engines also handle artistic content, providing or integrating with authoring tools to ease the process of creating high-fidelity games. In this course, we will discuss the problems game engines attempt to solve, examine how current state-of-the-art engines address these problems, and create our own engines based on what we learn. We will cover both the content authoring and runtime aspects of engines. Coursework will consist of frequent, tightly-scoped programming and system design assignments; expeditions through game engine source code; and two group projects and #8212; one in an engine created from scratch, and one that requires modification of an existing engine. Prerequisites: Students will be expected to be fluent in at least one programming language. We will be working with C++, Javascript, and a smattering of Python. We will be using git for version control and code sharing. The assignments in the course will be designed to be completed on an OSX or Linux workstation (e.g. the IDeATe "virtual cluster"). Working with Windows will be possible, but might require extra effort. We will be building a 3D model pipeline around Blender, but no prior knowledge of the tool will be assumed.
Prerequisites: 62-150 Min. grade C or 15-213 Min. grade C or 15-104 Min. grade C or 15-112 Min. grade C

16-467 Introduction to Human Robot Interaction

Spring: 12 units
The field of human-robot interaction (HRI) is fast becoming a significant area of research in robotics. The basic objective is to create natural and effective interactions between people and robots. HRI is highly interdisciplinary, bringing together methodologies and techniques from robotics, artificial intelligence, human-computer interaction, psychology, education, and other fields. This course is primarily lecture-based, with in-class participatory mini-projects, homework assignments, a group term project that will enable students to put theory to practice, and a final. The topics covered will include technologies that enable human-robot interactions, the psychology of interaction between people and robots, how to design and conduct HRI studies, and real-world applications such as assistive robots. This course has no prerequisites, but some basic familiarity with robots is recommended (programming knowledge is not necessary, but is useful for the term project).

Course Website: http://harp.ri.cmu.edu/courses (http://harp.ri.cmu.edu/courses/)

16-469 Innovation and Shared Prosperity: Community-engagement for change

Fall: 12 units
How might we, as a community of learners, utilize our collective talents for innovation and shift our society towards greater justice? In this course we will cover the historical and social context of university-community engagement, discuss best practices in engagement efforts, and operationalize emergent strategy alongside design justice principles. Learnings from this course will foster the growth of lifelong dispositions and habits that can empower learners to chart a course for their personal careers that are consonant with community empowerment and societal equity. This class is for individuals interested in pursuing a career at the intersection of technology and societal equity or for individuals who are interested in issues of justice and equity more broadly. Learning methods for this course will include readings, reflections, and in-class discussions. Students in this class will be asked to draw on their own experiences and to explore case studies. We also anticipate that students will directly engage with local community as facilitated through existing connections with the Center for Shared Prosperity.

16-474 Robotics Capstone

Spring: 12 units
In this course students refine the design of, build, integrate, test, and demonstrate the robot they designed in the prerequisite Systems Engineering course (16-450). The students are expected to continue to apply the process and methods of systems engineering to track requirements, evaluate alternatives, refine the cyberphysical architectures, plan and devise tests, verify the design, and validate system performance. The course consists of lectures, class meetings, reviews, and a final demonstration. Lectures cover special topics in project management. During class meetings the students and instructor review progress on the project and discuss technical and project-execution challenges. There are three major reviews, approximately at the end of each of the first three months of the semester. For each review, students give a presentation and submit an updated version of the System Design and Development Document. The course culminates in a System Performance Validation Demonstration at the end of the semester. Students also hold a special demonstration of their robotic system for the broader Robotics community.
Prerequisite: 16-450 Min. grade C

16-480 IDeATe: Creative Soft Robotics

Spring: 10 units
This experimental course offers unique topics situated at the intersection of robotics research and the arts, with a specific research focus that varies each semester. In this course, students survey the state of an emerging research area, then design and fabricate experimental systems and artworks on the theme. Students are guided through literature search and technical paper analysis to identify opportunities and techniques. The textual study spans contemporary robotics and arts literature. The project component is research-focused and explores novel techniques in design, fabrication, programming, and control. The project sequence culminates in the collaborative design of expressive robotic systems which match technical innovation with a human need or artistic expression. The initial iteration of the course focuses on soft robotics, an emerging discipline centered on devices constructed from compliant materials that incorporate sensing and actuation. The literature survey spans soft robotics and kinetic sculpture. The projects center on fabricating forms that incorporate actuators and sensors using silicone rubber cast into 3D-printed and laser-cut molds. This course is offered by IDeATe and this iteration will satisfy minor requirements for IDeATe Soft Technologies or IDeATe Physical Computing.

Course Website: https://courses.ideate.cmu.edu/16-480 (https://courses.ideate.cmu.edu/16-480/)

16-595 Undergraduate Independent Study

All Semesters
For students to pursue an independent study with a Robotics Institute faculty member.

16-597 Undergraduate Reading and Research

All Semesters
Undergraduate Reading and Research enables students to gain academic credits for conducing independent studies in robotics. Students must work with a robotics faculty advisor to devise a specific objective, activities (such as reading, evaluating, designing, coding, building, or testing robotic systems) and metrics for evaluation of their performance by their advisor.

16-621 MSCV Project I

Spring: 12 units
The MSCV capstone project course is designed to give project teams additional feedback on their capstone project from peers and faculty. Every week, capstone teams will present their project PPFs (Past-Present-Future) reports. For the presenting teams, the capstone course will help develop presentation and communication skills. For the students participating as peer-reviewers, it will help develop critical thinking and the ability to give constructive advice.

Course Website: https://piazza.com/cmu/spring2019/16621 (https://piazza.com/cmu/spring2019/16621/)

16-622 MSCV Capstone

Fall: 12 units
The MSCV capstone project course is designed to give project teams additional feedback on their capstone project from peers and faculty. Every week, capstone teams will present their project PPFs (Past-Present-Future) reports. For the presenting teams, the capstone course will help develop presentation and communication skills. For the students participating as peer-reviewers, it will help develop critical thinking and the ability to give constructive advice.

16-623 Advanced Computer Vision Apps.

Fall: 12 units
Computer vision is a discipline that attempts to extract information from images and videos. Nearly every smart device on the planet has a camera, and people are increasingly interested in how to develop apps that use computer vision to perform an ever expanding list of things including: 3D mapping, photo/image search, people/object tracking, augmented reality etc. This course is intended for graduate students who are familiar with computer vision, and are keen to learn more about the applying state of the art vision methods on smart devices and embedded systems. A strong programming background is a must (at a minimum good knowledge of C/C++), topics will include using conventional computer vision software tools (OpenCV, MATLAB toolboxes, VLFeat, CAFFE, Torch 7), and development on iOS devices using mobile vision libraries such as GPUImage, Metal and fast math libraries like Armadillo and Eigen. For consistency, all app development will be in iOS and it is expected that all students participating in the class have access to an Intel-based MAC running OS X Mavericks or later. Although the coursework will be focused on a single operating system, the knowledge gained from this class will easily generalize to other mobile platforms such as Android etc.
Prerequisites: 16-385 or 16-720

Course Website: http://16623.courses.cs.cmu.edu

16-627 MSCV Seminar

Fall
(Only open to MSCV students.) MSCV students will be required to participate in this one-semester seminar course which will prepare them for the MSCV project starting in the Spring semester. The first part of this course will cover talks by computer vision and related faculty about the ongoing research, development programs related to Computer Vision at CMU. The second part of this course will include student/faculty tutorial on topics such as OpenCV, Dataset Creation, Mechanical Turk etc. The goal of this series is to get students acquainted with practical knowledge for a successful project. In the last month of the course, each lecture will cover upto four possible MSCV projects pitched by faculty or industrial sponsors. At the end of the course students will turn in their choices, and a faculty committee will assign them the final projects.

16-633 Special Topic: Robot Cognition and Learning

Spring: 12 units
This is open to both Grad and Undergrad students. This project class focuses on developing cognitive and learning systems for robots. Students will become familiar with and use state of the art software tools to build prototype systems, as well as how to evaluate these systems. The course project will involve implementing a cognitive/learning system on a real robot. For undergraduates, this course is an elective for the Robotics Major.

Course Website: https://www.cs.cmu.edu/~cga/cog/

16-639 Special Topic: Scalable Robotic Systems: Infrastructure Development/Deployment

Spring: 12 units
As robots continue to permeate various sectors such as healthcare, manufacturing, and autonomous transportation, the ability to build and scale robust robotic systems has become increasingly crucial. This course aims to bridge the gap between single-robot deployments and large-scale robotic systems, providing students with a comprehensive understanding of the processes and tools necessary to scale their robotic projects.

16-663 F1Tenth Autonomous Racing

Spring: 12 units
This hands-on, lab-centered course is for senior undergraduates and graduate students interested in the fields of artificial perception, motion planning, control theory, and applied machine learning. It is also for studentsinterested in the burgeoning field of autonomous driving. This course introduces the students to the hardware, software and algorithms involved in building and racing an autonomous race car. Every week, students take two lectures and complete an extensive hands-on lab. By Week 6, the students will have built, programmed and driven a 1/10th scale autonomous race car. By Week 10, the students will have learned fundamental principles in perception, planning and control and will race using map-based approaches. In the last 6 weeks, they develop and implement advanced racing strategies, computer vision and machine learning algorithms that will give their team the edge in the race that concludes the course.

16-664 Self-Driving Cars: Perception & Control

Fall: 12 units
This course will teach the theoretical underpinnings of self-driving car algorithms and the practical application of the material in hands-on labs. Topics will include deep learning, computer vision, sensor fusion, localization, trajectory optimization, obstacle avoidance, and vehicle dynamics.

16-665 Robot Mobility on Air, Land, & Sea

Fall: 12 units
Required core course for MRSD first-year students. Many robots are designed to move through their environments. Three prevalent environments on earth are land, air, and water. This course will explore the modeling, control, and navigation of ground-based (wheeled and legged), air-based (rotorcraft such as quadcopters), and water-based robots.

16-667 Autonomous Air Vehicle Design and Development

All Semesters: 12 units
OPEN TO GRADUATE AND UNDERGRADUATE STUDENTS; Autonomous Air Vehicles are finding new applications in Civil Air Transportation and Emergency Response scenarios. They carry passengers and valuable supplies and must be certified to operate in both urban and rural areas, close to people, buildings, highways, mountains, and dense forest canopies. This presents significant challenges to perception, control systems, and navigation through austere environments. The design limits and flight operations of the aircraft must be understood to be certified by the FAA. In Autonomous Air Vehicle Development, students will design, develop, and test prototype autonomous aircraft for specific missions defined by the new HeroX GoAero Challenge. This multidisciplinary course will go from concept to test and challenge students to apply sound theoretic approaches to a practical design. Students will learn how to design and build resilient autonomous air vehicle systems and the challenges of real-world design, operations, certification, and testing.

Course Website: https://www.herox.com/goaero (https://www.herox.com/goaero/)

16-675 Manufacturing Futures

Spring: 12 units
The course will introduce an array of technologies that will contribute to the future of making things and will be organized into 4 logical modules that will culminate in a team-based design project. Module 1 (Manufacturing Visions and Design Methodolgy): David Bourne. Module 2 (Manufacturing Processes and Process Tradeoffs): Brandon Bodily. Module 3 (Electronic Manufacturing): Rahul Panat. Module 4 (Workforce Development) : David Bourne.

16-682 Robotic Systems Development Project Course II

Fall: 15 units
Required core course for MRSD second-year students. This course is the second semester in a two-semester sequence intended to enable student teams to design and implement robot systems from the requirements development phase through implementation, verification, and demonstration of a working prototype. Teams of 4-5 students continue work on a project provided by industrial and academic partners, refine design requirements, refine or create new subsystems, and integrate and demonstrate the full system.

16-714 Advanced Control for Robotics

Fall: 12 units
This course will discuss advanced control algorithms that can make robots behave more intelligently. This course is directed to studentsprimarily graduate although talented undergraduates are welcome as wellinterested in advanced control.
Prerequisite: 16-711 Min. grade C

16-715 Advanced Robot Dynamics and Simulation

Fall: 12 units
This course explores the fundamental mathematics behind modeling the physics of robots, as well as state-of-the-art algorithms for robot simulation. We will review classical topics like Lagrangian mechanics and Hamilton's Principle of Least Action, as well as modern computational methods like discrete mechanics and fast linear-time algorithms for dynamics simulation. A particular focus of the course will be rigorous treatments of 3D rotations and non-smooth contact interactions (impacts and friction) that are so prevalent in robotics applications. We will use numerous case studies to explore these topics, including quadrotors, fixed-wing aircraft, wheeled vehicles, quadrupeds, humanoids, and manipulators. Homework assignments will focus on practical implementation of algorithms and a course project will encourage students to apply simulation methods to their own research.

16-720 Computer Vision

Fall and Spring: 12 units
Section A is a required core course for MRSD first-year students, and Section B is a required core course for MSCV students. This course introduces the fundamental techniques used in computer vision, that is, the analysis of patterns in visual images to reconstruct and understand the objects and scenes that generated them. Topics covered include image formation and representation, camera geometry, and calibration, computational imaging, multi-view geometry, stereo, 3D reconstruction from images, motion analysis, physics-based vision, image segmentation and object recognition. The material is based on graduate-level texts augmented with research papers, as appropriate. Evaluation is based on homeworks and a final project. The homeworks involve considerable Python programming exercises. Texts recommended but not required: Title: "Computer Vision Algorithms and Applications" Author: Richard Szeliski Series: Texts in Computer Science Publisher: Springer ISBN: 978-1-84882-934-3 Title: "Computer Vision: A Modern Approach" Authors: David Forsyth and Jean Ponce Publisher: Prentice Hall ISBN: 0-13-085198-1

Course Website: http://www.andrew.cmu.edu/course/16-720/

16-725 (Bio)Medical Image Analysis

Spring: 12 units
Students will gain theoretical and practical skills in 2D, 3D, and 4D biomedical image analysis, including skills relevant to general image analysis. The fundamentals of computational medical image analysis will be explored, leading to current research in applying geometry and statistics to segmentation, registration, visualization, and image understanding. Additional and related covered topics include de-noising/restoration, morphology, level sets, and shape/feature analysis. Students will develop practical experience through projects using the latest version of the National Library of Medicine Insight Toolkit (ITK) and SimpleITK, a popular open-source software library developed by a consortium of institutions including Carnegie Mellon University and the University of Pittsburgh. In addition to image analysis, the course will include interaction with radiologists and pathologist(s). *** Lectures are at CMU and students will visit clinicians at UPMC. Some or all of the class lectures may also be videoed for public distribution, but students may request to be excluded from distributed video. 16-725 is a graduate class, and 16-425 is a cross-listed undergraduate section. 16-425 is new this year, and has substantially reduced requirements for the final project and for the larger homework assignments, nor does it require shadowing the clinicians. Prerequisites: Knowledge of vector calculus, basic probability, and either C++ or python, including basic command-line familiarity and how to pass arguments to your own command-line programs. Extensive expertise with C++ and templates is not necessary, but some students may find it helpful.

Course Website: http://www.cs.cmu.edu/~galeotti/methods_course/

16-726 Learning-based Image Synthesis

Spring: 12 units
This course introduces machine learning methods for image and video synthesis. The objectives of synthesis research vary from modeling statistical distributions of visual data, through realistic picture-perfect recreations of the world in graphics, and all the way to providing interactive tools for artistic expression. Key machine learning algorithms will be presented, ranging from classical learning methods (e.g., nearest neighbor, PCA) to deep learning models (e.g., ConvNets, NeRF, deep generative models, including GANs, VAEs, autoregressive models, and diffusion models). Finally, we will discuss image and video forensics methods for detecting synthetic content. In this class, students will learn to build practical applications and create new visual effects using their own photos and videos.

16-730 Robotics Business

Spring: 12 units
This course introduces and develops business concepts that will be useful to new and existing companies, while focusing on robotic technology exemplars. The concepts begin with how to identify a new idea to for a business that can be effectively started. Initial ideas often start as a grandiose plan to change the world and these plans are legitimately the fuel that drive new businesses forward. However, when a company starts (e.g., builds a prototype or writes a first line of code), what is the least product a company can produce that customers still want and need? This kernel and #8212; extracted from the "big plan" and #8212; is a Minimal Viable Product (MVP). Once an MVP business kernel is formulated, we will learn and study how to understand customer needs, how to market a new idea and how raise and manage money for a new business entity. These steps abridge information that can be found in an MBA curriculum, but engineers and scientists focused on the technical side will need this information to participate in the process of building companies. In parallel, we will investigate the marketplace through the stock market. The stock market is a powerful window into the world of business. In other words, when a new business is built it has to live inside the competitive environment of every other business. To understand this eco-system, we will follow several companies in-situ as they go through their own ups-and-downs within the business world. The course is project based. Each student will either build their own business concept, or they will build an improvement plan that would be targeted to improve an existing business. Professor Bourne is a founding member of the Robotics Institute(1979) and has taught business concepts within the Tepper Business School and the Robotics Institute since 1988. In addition, he is the President of his own company Design One Software.

16-735 Ethics and Robotics

Intermittent: 12 units
This course contextualizes robotics, AI, and machine learning within cultural conversation, ethics, and power relationships in society. It will draw upon "AI and Humanity" as well as numerous other texts, including Mindless by Simon Head, Drone Theory by Gr and #233;goire Chamayou, and news articles. The course will culminate in team-based design and futuring project addressing the ways in which robotic technologies will influence society and values in the near future. Our target audience is students who will participate in computer science and robotics research and can use this course to inform future research and career decisions.

Course Website: https://vdean.github.io/16-735-ethics-robotics.html

16-737 Special Topic: Research to Startup: creating a startup from robotics research

Intermittent: 12 units
(This course is offered only to Ph.D. students in SCS, or with instructor permission.) This course is for Ph.D. students interested in exploring turning their research into a startup. Advances in AI and robotics have opened exciting opportunities for robotics-based startups. But with that comes challenges. In this class, students will form small teams to take an idea based in part on their research and work through the early steps of converting it into a company. This will require taking a dispassionate view of your research as a product or service and assessing its market and value. Each team will work through customer discovery, vetting ideas, creating and communicating a vision and strategy, fundraising, and building a product. We will have guest lectures and discussions where we will learn from the experiences of people who have created startups. We will learn about CMU resources to help with IP and technology transfer and discuss open-source strategies. We will discuss leveraging Ph.D. students' honed research skills to be successful company founders and #8212;e.g., related work investigations, presentations, and time management. We will emphasize the difference between research and commercial software and provide tools, technologies, and methodologies for a software development lifecycle. We cannot cover everything you need to know in one semester, but we will expose you to the essential aspects necessary to get started.

16-740 AI for Manipulation

Spring: 12 units
Manipulation is the process of changing the state of objects through direct physical interactions. To perform manipulation tasks in unstructured environments, autonomous robots will need to learn about the objects in their surroundings as well as the skills required to manipulate and change the state of these objects. In this course, we explore the use of machine learning and data-driven algorithms for robot manipulation. The course introduces students to the wide variety of challenges posed by manipulation tasks, and how these challenges can be formulated as learning problems. Students are taught how these problems can be solved using machine learning techniques. The types of machine learning methods covered in this course include supervised, unsupervised, active, and reinforcement learning methods. The course includes both lectures and guided paper discussions.

16-741 Mechanics of Manipulation

Fall: 12 units
Mechanics of Manipulation is a graduate level course that dives into the fundamentals of robotic manipulation. Through this course you will learn the kinematics, statics, and dynamics of robotic manipulators as they interact with the world to accomplish tasks. You will gain experience with the intelligent use of kinematic constraint, gravity, and frictional forces. Additional topics include rigid body mechanics, automatic planning based on mechanics, deformable manipulation, and simulation of dynamic manipulation. Applications of robotic manipulation are drawn from physical human-robot interaction, manufacturing, and other domains.

Course Website: http://www.cs.cmu.edu/afs/cs/academic/class/16741-s07/www/index.html (http://www.cs.cmu.edu/afs/cs/academic/class/16741-s07/www/)

16-742 Geometry of Locomotion

Fall: 12 units
This course introduces geometric methods for the analysis of locomoting systems. Focusing on the kinematics of locomoting systems, the course covers topics from differential geometry, geometric mechanics, and motion planning . Specific topics include configuration spaces, manifolds, groups, Lie groups, representations of velocity, holonomic and nonholonomic constraints, constraint curvature, response to cyclic inputs and distance metrics. The primary goal of this class is to develop an intuitive understanding of these concepts and how they are used in locomoting systems, rather than working through a set of formal proofs and derivations. We do, however, incorporate enough mathematical formalism for this class to serve as a starting point for further investigation into this topic area. We also call upon biological data, when available, and relate to the mathematical formalisms in the class.

16-745 Optimal Control and Reinforcement Learning

Spring: 12 units
This is a course about how to make robots move through and interact with their environment with speed, efficiency, and robustness. We will survey a broad range of topics from nonlinear dynamics, linear systems theory, classical optimal control, numerical optimization, state estimation, system identification, and reinforcement learning. The goal is to provide students with hands-on experience applying each of these ideas to a variety of robotic systems so that they can use them in their own research.

Course Website: http://www.cs.cmu.edu/~cga/dynopt/

16-748 Underactuated Robots

Fall: 12 units
People and animals move through and interact with the world in a fundamentally dynamic way. In the vast majority of cases the same cannot be said for robots. In fact, many conventional approaches to motion planning and robot control attempt to explicitly cancel out the dynamics associated with different tasks. This class will consider underactuated robots, systems that do not have full control over their state and therefore cannot be planned for or controlled via conventional methods. Our goal will be to make novel locomoting robots act more "naturally." This class will highlight the relationship between conventional ideas from deterministic motion planning and control design (e.g., dynamic programming and linear-quadratic regulators) and their contemporary counterparts, many of which help form the analytical basis for the probabilisitic reasoning that underlies contemporary AI systems (e.g., POMDPs). Note that this course is inspired by and, for the most part, will follow the format of "Underactuated Robotics: Learning, Planning, and Control for Efficient and Agile Machines" created by Prof. Russ Tedrake at MIT. We will take several tangents, but the course materials provided by Prof. Tedrake through MIT Open Courseware are an incredible resource for this course (and really just in general).

16-761 Mobile Robots

Spring: 12 units
The course is targeted to graduate level students. The lectures will develop the fundamentals for enabling autonomy of multi rotor aerial vehicles. Students will individually complete assignments related to autonomous quadrotor flight, including motion planning, control, dynamics, state estimation, and perception. The class will culminate in a final project in which students may work together in groups or individually to enhance the autonomy capabilities developed through the assignments.

Course Website: https://mr-cmu.github.io

16-762 Mobile Manipulation

Spring: 12 units
In this project-based course, you'll learn about mobile manipulation through hands-on experience working with real mobile manipulators. You'll gain experience with teleoperation, autonomy, perception, navigation, manipulation, and human-robot interaction, all within the context of mobile manipulators. You'll also learn about robot design, collaborative research, and applications for mobile manipulators.

16-765 Robotics & AI for Agriculture

Spring: 12 units
Robotics and artificial intelligence technologies have the potential to increase the efficiency, long-term sustainability, and profitability of agricultural production methods. This class will introduce common aspects of agricultural systems, the AI/Robotics tools that are being used to address them, and key research challenges looking forward. Technical topics include IoT sensor networks, in-field computer vision, 3D crop mapping and modeling, mobile robot navigation, and robotic manipulation of plants. Course sessions will be split evenly between lectures by the instructor and student-led discussion of relevant papers from the contemporary research literature.

16-778 Mechatronic Design

Spring: 12 units
Mechatronics is the synergistic integration of mechanism, electronics, and computer control to achieve a functional system. This course is a semester-long multidisciplinary capstone hardware project design experience in which small (typically four-person) teams of electrical and computer engineering, mechanical engineering and robotics students deliver an end-of-course demonstration of a final integrated system capable of performing a mechatronic task. Throughout the semester, the students design, configure, implement, test and evaluate in the laboratory devices and subsystems culminating in the final integrated mechatronic system. Lectures will complement the laboratory experience with comparative surveys, operational principles, and integrated design issues associated with the spectrum of mechanism, microcontroller, electronic, sensor, and control components.

Course Website: http://www.ece.cmu.edu/courses/items/18578.html

16-782 Planning and Decision-making in Robotics

Fall: 12 units
Planning and Decision-making are critical components of autonomy in robotic systems. These components are responsible for making decisions that range from path planning and motion planning to coverage and task planning to taking actions that help robots understand the world around them better. This course studies underlying algorithmic techniques used for planning and decision-making in robotics and examines case studies in ground and aerial robots, humanoids, mobile manipulation platforms and multi-robot systems. The students will learn the algorithms and implement them in a series of programming-based projects.

16-785 Integrated Intelligence in Robotics: Vision Language Planning

Intermittent: 12 units
This is a project-oriented course that covers interdisciplinary topics on cognitive intelligence in robotic systems. Cognitive abilities constitute high-level, humanlike intelligence that exhibits reasoning or problem-solving skills. Such abilities as semantic perception, use of language, and task planning can be built on top of low-level robot autonomy. The topics covered generally bridge across multiple technical areas, for example, vision-language intersection and language-action/plan grounding. The project theme in Spring 2023 is "movie making" that presents various robotics and machine learning challenges ranging from content generation such as scenario generation or scene/video synthesis/editing to robotics automation such as autonomous camera control or autonomous stop-motion control. This course is composed of 50% lectures and 50% seminar classes. The course objectives will also put a special emphasis on learning research skills, e.g., problem formulation, literature review, ideation, evaluation planning, results analysis, and hypothesis verification. The course is discussion intensive, and thus attendance is required.

Course Website: http://www.cs.cmu.edu/~jeanoh/16-785/

16-791 Applied Data Science

Spring: 12 units
This course explores the rapidly developing field of data science in the context of its pragmatic applications. Applied Data Science strives to achieve three main goals. The first is to optimize the efficacy of decision making by human managers. The second is to maximize the utilization of available data, so that no important clue is ever missed. The third is to improve understanding of data and the underlying processes that produce it. This course aims at building skills required to systematically achieve those goals in practice. The students will gain and solidify awareness of the most prevalent contemporary methods of Data Science, and develop intuition needed for assessing practical utility of the studied topics in application scenarios. They will be able to learn how to formulate analytic tasks in support of project objectives, how to define successful analytic projects, and how to evaluate utility of existing and potential applications of the discussed technologies in practice.

16-792 Applied Machine Learning

Intermittent
This course explores the rapidly developing field of machine learning in the context of its pragmatic applications. The domain of Applied Machine Learning strives to achieve three main goals. The first is to build effective models to optimize the efficacy of decision-making. The second is to maximize the utilization of available data so that no important clue is ever missed. The third is to gain or improve an understanding of data and the underlying processes that produce it. Students are required to register for 9 units to receive credit for lectures but may also register for 12 units which will include 3 units of capstone project.

16-820 Advanced Computer Vision

Fall: 12 units
16-820 is a required core course for MSCV students and is intended to move at a slightly faster pace compared to 16-720. This course introduces the fundamental techniques used in computer vision, that is, the analysis of patterns in visual images to reconstruct and understand the objects and scenes that generated them. Topics covered include camera geometry and calibration, multi-view stereo, 3D reconstruction, image detection, segmentation, and tracking, and physics-based vision. The homeworks involve considerable Python programming exercises.

16-823 Physics-based Methods in Vision (Appearance Modeling)

Intermittent: 12 units
Everyday, we observe an extraordinary array of light and color phenomena around us, ranging from the dazzling effects of the atmosphere, the complex appearances of surfaces and materials, and underwater scenarios. For a long time, artists, scientists, and photographers have been fascinated by these effects, and have focused their attention on capturing and understanding these phenomena. In this course, we take a computational approach to modeling and analyzing these phenomena, which we collectively call "visual appearance". The first half of the course focuses on the physical fundamentals of visual appearance, while the second half of the course focuses on algorithms and applications in a variety of fields such as computer vision, graphics and remote sensing and technologies such as underwater and aerial imaging.
Prerequisites: 16-385 or 16-720 or 15-462 or 16-820

Course Website: http://www.cs.cmu.edu/afs/cs/academic/class/16823-f06/

16-824 Visual Learning and Recognition

Spring: 12 units
This graduate-level computer vision course focuses on representation and reasoning for large amounts of data (images, videos, associated tags, text, GPS locations, etc.) toward understanding the visual world surrounding us. We will be reading an eclectic mix of classic and recent papers on topics including Theories of Perception, Mid-level Vision (Grouping, Segmentation, Poses), Object and Scene Recognition, 3D Scene Understanding, Action Recognition, Multimodal Perception, Language and Vision Models, Deep Generative Models, Efficient Neural Networks, and more. We will cover a wide range of supervised, semi-supervised, self-supervised, and unsupervised approaches for each topic above.
Prerequisites: 15-781 Min. grade B or 16-720 Min. grade B or 16-722 Min. grade B or 10-701 Min. grade B or 16-385 Min. grade B

Course Website: https://visual-learning.cs.cmu.edu/

16-825 Learning for 3D Vision

Spring: 12 units
Any autonomous agent we develop must perceive and act in a 3D world. The ability to infer, model, and utilize 3D representations is therefore of central importance in AI, with applications ranging from robotic manipulation and self-driving to virtual reality and image manipulation. While 3D understanding has been a longstanding goal in computer vision, it has witnessed several impressive advances due to the rapid recent progress in (deep) learning techniques e.g. differentiable rendering, single-view 3D prediction. The goal of this course is to explore this confluence of 3D Vision and Learning-based Methods.

16-831 Introduction to Robot Learning

Fall and Spring: 12 units
Robots need to make sequential decisions to operate in the world and generalize to diverse environments. How can they learn to do so? This is what we call the "robot learning" problem and it spans topics in machine learning, visual learning and reinforcement learning. In this course, we will learn the fundamentals of topics in machine/deep/visual/reinforcement-learning and how such approaches are applied to robot decision making. We will study fundamentals of: 1) machine (deep) learning with emphasis on approaches relevant for cognition, 2) reinforcement learning: model-based, model-free, on-policy (policy gradients), off-policy (q-learning), etc.; 2) imitation learning: behavior cloning, dagger, inverse RL and offline RL.; 3) visual learning geared towards cognition and decision making including topics like generative models and their use for robotics, learning from human videos, passsive internet videos, language models; and 4) leveraging simulations, building differentiable simulations and how to transfer policies from simulation to the real world; 5) we will also briefly touch topics in neuroscience and psychology that provide cognitive motivations for several techniques in decision making. Throughout the course, we will look at many examples of how such methods can be applied to real robotics tasks as well as broader applications of decision making beyond robotics (such as online dialogue agents etc.). The course will provide an overview of relevant topics and open questions in the area. There will be a strong emphasis on bridging the gap between many different fields of AI. The goal is for students to get both the high-level understanding of important problems and possible solutions, as well as low level understanding of technical solutions. We hope that this course will inspire you to approach problems in congnition and embodied learning from different perspectives in your research. (As of 3/21/2023)

Course Website: https://docs.google.com/document/d/1Lx2IkUMvtETH52ZMl7eySZX3yLWQnED746ET9g_tte0/edit?usp=sharing (https://docs.google.com/document/d/1Lx2IkUMvtETH52ZMl7eySZX3yLWQnED746ET9g_tte0/edit/?usp=sharing)

16-833 Robot Localization and Mapping

Spring: 12 units
Robot localization and mapping are fundamental capabilities for mobile robots operating in the real world. Even more challenging than these individual problems is their combination: simultaneous localization and mapping (SLAM). Robust and scalable solutions are needed that can handle the uncertainty inherent in sensor measurements, while providing localization and map estimates in real-time. We will explore suitable efficient probabilistic inference algorithms at the intersection of linear algebra and probabilistic graphical models. We will also explore state-of-the-art systems.

Course Website: http://frc.ri.cmu.edu/~kaess/teaching/16833/Spring2018 (http://frc.ri.cmu.edu/~kaess/teaching/16833/Spring2018/)

16-845 Insects and Robots

Fall: 12 units
This course will cover all facets of modeling, design, fabrication, and analysis of robots operating on the insect scale, with a microrobotics perspective. Insects can perform different tasks, such as manipulation or locomotion, with their small scale bodies varying from 200m to 16cm length. Similarly, we can define a micro-robotic system as an autonomous or semi-autonomous device with features on the micron scale or that make use of micron-scale physics for mobility or manipulation of objects. Due to their small size scales, microrobots will encounter difficulties unlike their macro-scale counterparts, in terms of fabrication and autonomy. In this project-based course, our aim will be on learning the physics of scaling, fabrication paradigms, actuation and sensing strategies, with numerous case studies, and to build an insect-inspired robotic system. We will also discuss multiple applications such as surgical robotics, mobile microrobots, multi-agent systems, and micro/nano manipulation.

16-848 Hands: Design and Control for Dexterous Manipulation

Spring: 12 units
Research related to hands has increased dramatically over the past decade. Robot hand innovation may be at an all time high, with new materials and manufacturing techniques promoting an explosion of ideas. Hands have become a priority in virtual reality and telepresence. Even the study of how people use their hands is seeing the growth of new ideas and themes. With all of this attention on hands, are we close to a breakthrough in dexterity, or are we still missing some things needed for truly dexterous manipulation? In this course, we will survey robotic hands and learn about the human hand with the goal of pushing the frontiers on hand design and control for dexterous manipulation. We will consider the necessary kinematics and dynamics for dexterity, what sensors are required to carry out dexterous interactions, the importance of reflexes and compliance, the role of machine learning in grasping and manipulation, and the challenge of uncertainty. We will explore state of the art manufacturing and design techniques, including innovations in soft robotics and embedded sensing. We will examine the human hand: its structure, sensing capabilities, human grasp choice and control strategies for inspiration and benchmarking. Students will be asked to present one or two research papers, participate in discussions and short research or design exercises, and carry out a final project.

Course Website: http://graphics.cs.cmu.edu/nsp/course/16899-s18/

16-855 Special Topics: Tactile Sensing and Haptics

Spring: 12 units
Touch is an important perception modality for both humans and robots. This course aims at providing an overview of the touch perception system for both robots and humans, and provide students with some hands-on experience with the popular touch sensors and devices. On the side of robot sensing, the course will cover the topics on the working principles and designs of robot touch sensors, signal processing algorithms for tactile sensing, and the application of tactile sensing in different robotic tasks; on the side of haptics, the course will introduce the neurological and cognitive study in human haptic system, and the designs and applications of haptic devices that provide a human-machine interface. The human-machine interface is a core part of Virtual Reality (VR) and teleoperation of robots when touch is involved. The course includes lectures, research paper presentation and discussion, and course projects with tactile sensors or haptic devices.

16-873 Spacecraft Design-Build-Fly Laboratory

Fall and Spring: 12 units
Spacecraft design is a truly interdisciplinary subject that draws from every branch of engineering. This course integrates broad skillsets from mechanical engineering, electrical and computer engineering, computer science, and robotics toward the goal of designing, building, testing, and flying a small spacecraft over the course of two semesters. Students will engage directly in all aspects of the spacecraft mission lifecycle from initial requirements definition through mission operations. YES, WE ARE REALLY GOING TO LAUNCH A SATELLITE INTO SPACE AS PART OF THIS COURSE. Students will work in subsystem teams, each focusing on some aspect of the spacecraft, but will be exposed to many different disciplines and challenges. Practical, hands-on, engineering skills will be emphasized, along with building and testing physical hardware and flight software.

16-874 Spacecraft Design-Build-Fly Laboratory 2

Spring: 12 units
(ENROLLMENT IS BY INSTRUCTOR APPROVAL ONLY) This course is a continuation of 16-/18-873, and together these two courses make a sequence culminating in the launch of the satellite designed and built over two consecutive semesters. Spacecraft design is a truly interdisciplinary subject that draws from every branch of engineering. This course integrates broad skillsets from mechanical engineering, electrical and computer engineering, computer science, and robotics toward the goal of designing, building, testing, and flying a small spacecraft over the course of two semesters. In this, the second semester of the two-semester sequence, students will work in subsystem teams to fabricate spacecraft components and finally integrate them into a complete spacecraft by the end of the semester. YES, WE ARE REALLY GOING TO LAUNCH A SATELLITE INTO SPACE AS PART OF THIS COURSE. Practical, hands-on, engineering skills will be emphasized, along with building and testing physical hardware and flight software.

16-878 Advanced Mechatronic Design

Fall: 12 units
This course is designed for students who have a background in mechatronics by having taken a mechatronics design course or through practice. The course will be a combination of laboratories and lectures and will culminate in a class project. The topics covered will be microcontroller hardware subsystems: timer systems, PWM, interrupts; analog circuits, operational amplifiers, comparators, signal conditioning, interfacing to sensors, actuator characteristics and interfacing; C language features for embedded software, register level programming, hardware abstraction layers, event driven programming, state machines, state charts.

16-879 Medical Robotics

Fall: 12 units
This course presents an overview of medical robotics intended for graduate students and advanced undergraduates. Topics include robot kinematics, registration, navigation, tracking, treatment planning, and technical and medical aspects of specific applications. The course will include guest lectures from robotics researchers and surgeons, as well as observation of surgical cases. The course is open to non-majors who have the requisite background.

16-880 Special Topics: Engineering Haptic Interfaces

Spring: 12 units
This course focuses on addressing challenges in the field of haptics from an engineer's perspective. We will begin by studying human haptic perception and an introduction into psychophysics. We will then study the design and control of haptic systems which provide touch feedback to a user. The class format will include lectures, discussion, paper presentations, laboratories and assignments using hardware that will be shipped to the students, and a class project. This class is designed to be a graduate/advanced undergraduate course and requires a background in dynamic systems, mechatronics, and basic programming. Mechanical prototyping, robotics, and feedback control knowledge are useful skills for this class but are not required.

16-881 Seminar Deep Reinforcement Learning for Robotics

Spring: 12 units
Deep RL has a lot of promise to teach robots how to choose actions to optimize sequential decision-making problems, but how can we make deep RL work in the real world? This is a seminar course in which we read papers related to deep learning for robotics and analyze the tradeoffs between different approaches. We will read mostly state-of-the-art papers that were very recently published (e.g. recent CoRL, RSS), but we will also look at some older papers that use different approaches. The goals of the course are to 1) understand what is needed to make deep learning work for robotics 2) analyze the tradeoffs between different approaches. Each class, 2 papers will be presented. These papers will both achieve a similar robotics task but will use different learning-based approaches. The class will discuss these papers and try to understand the strengths and limitations of the approach described in each paper. The list of papers that we will be discussing this year is still to be determined; please see the website for the list of papers that we have used in past semesters: https://sites.google.com/view/16-881-cmu/paper-lists?authuser=0 The seminar is a great followup course to 16-831, 16-884, 10-403, or 10-703.

Course Website: https://sites.google.com/view/16-881-cmu/home?authuser=0 (https://sites.google.com/view/16-881-cmu/home/?authuser=0)

16-882 Systems Engineering and Applied Robotics

Spring: 12 units
This course is intended for graduate students of all disciplines who are interested in learning about Systems Engineering and its application in the development of interdisciplinary technical systems. The first part of the course introduces students to the models, methods, and techniques of Systems Engineering. The second part of the course is a study on the adaptation of Systems Engineering in the development of novel robotic systems in applied fields. Each student in the class will perform a semester long study on a special topic in Systems Engineering and a critical evaluation of the process in the development of innovative robotics for applications in space, mining, agriculture, mining, and others.

16-883 Special Topics: Provably Safe Robotics

Spring: 12 units
Safe autonomy has become increasingly critical in many application domains. It is important to ensure not only the safety of the ego robot, but also the safety of other agents (humans or robots) that directly interact with the autonomy. For example, robots should be safe to human workers in human-robot collaborative assembly; autonomous vehicles should be safe to other road participants. For complex autonomous systems with many degrees of freedom, safe operation depends on the correct functioning of all system components, i.e., accurate perception, optimal decision making, and safe control. This course deals with both the design and the verification of safe robotic systems. From the design perspective, we will talk about how to assure safety through planning, prediction, learning, and control. From the verification perspective, we will talk about verification of deep neural networks, safety or reachability analysis for closed loop systems, and analysis of multi-agent systems.

Course Website: http://www.cs.cmu.edu/~cliu6/provably-safe-robotics.html

16-884 Deep Learning for Robotics

Fall: 12 units
The goal of this course is to study relevant topics towards building intelligent robots that can learn to act and perceive in the real world. The course material should be a self-contained collection of key topics from the intersection of four research areas geared towards this common goal: a) Robot Learning and amp; Deep RL; (b) Computer Vision; (c) Control; (d) Psychology and amp; Neuroscience. This course is geared mainly towards learning and brainstorming. There will be two classes every week. In this first class, instructor will present an in-depth overview of a topic, and then in the second class, students will present instructor-assigned papers related to that topic. There will be no homeworks and just a course project. In the first quarter, we will cover state-of-the-art topics in robot learning (deep RL, inverse RL, etc.) and control (optimal control, dynamic movement primitives, etc.) by studying classical and recent papers in the area. In the second quarter, we will study the role of perception in control and vice-versa to build methods that can learn from high-dimensional raw sensory input. In the third quarter, we will discuss the state of the current understanding of how the brain integrates action and perception. We will also discuss relevant papers from ontogeny (child development literature in Psychology) and phylogeny (evolutionary development literature in Biology) of biological animals that have inspired ideas in learning and robotics. Finally, in the fourth quarter, we will bring these ideas together to brainstorm potential high-level directions that could guide the development of intelligent robots.

16-885 Special Topics: Tactile Sensing and Haptics

Fall: 12 units
Touch is an important perception modality for both humans and robots. This course aims at providing an overview of the touch perception system for both robots and humans. On the side of robot sensing, the course will cover the designs of robot touch sensors, signal processing algorithms for tactile sensing, and the application of tactile sensing in different robotic tasks; on the side of haptics, the course will introduce the neurological and cognitive study in the human haptic system, and the designs and applications of haptic devices that provide a human-machine interface. The course incorporates lectures, research paper presentations, and discussion. The combination of different modules aims to present both the basics and state-of-art research directions in the field.

16-886 Special Topics: Models & Algorithms for Interactive Robotics

Spring: 12 units
Robot interaction with humans is inevitable: autonomous cars navigate through crowded cities, assistive robots help end-users with daily living tasks, and human engineers iteratively tune robot objective functions. In this graduate seminar class, we will build the mathematical foundations for modeling human-robot interaction, investigate algorithms for robot learning from human data, and develop the tools to analyze the safety and reliability of robots deployed around people. The approaches covered will draw upon a variety of tools such as optimal control, dynamic game theory, Bayesian inference, and modern machine learning. Throughout the class, there will also be several guest lectures from experts in the field. Students will practice essential research skills including reviewing papers, debating, writing project proposals, and technical communication.

16-887 Special Topic: Robotic Caregivers and Intelligent Physical Collaboration

Spring: 12 units
Robotics researchers and futurists have long dreamed of robots that can serve as caregivers. In this project-based course, you'll learn about intelligent physical human-robot collaboration and opportunities for robots that contribute to caregiving. You'll gain hands-on experience with teleoperation, autonomy, perception, navigation, manipulation, human-robot interaction, and machine learning. You'll also learn about robot design, collaborative research, and healthcare robotics.

Course Website: https://zackory.com/rc2023/

16-888 Special Topic: Foldable Robots: Origami-inspired design meets mechatronics

Intermittent: 12 units
The way we make robots have changed dramatically since the limitations on the material space was removed. Instead of using "nuts-and-bolts" approach that helped us to make robust, rigid, industrial robots, we can make light-weight, compliant, conformable robots out of paper, fabric, and polymers. In this class, we will explore foldable robots with a multifaceted perspective: Kinematics, design, fabrication, control, and application. We will design and manufacture mechanisms for targeted applications, such as manipulation, bio-inspiration, medical, architecture, using laminates with integrated joints and limited number of actuators.

16-889 Special Topic: Learning for 3D Vision

Spring: 12 units
Any autonomous agent we develop must perceive and act in a 3D world. The ability to infer, model, and utilize 3D representations is therefore of central importance in AI, with applications ranging from robotic manipulation and self-driving to virtual reality and image manipulation. While 3D understanding has been a longstanding goal in computer vision, it has witnessed several impressive advances due to the rapid recent progress in (deep) learning techniques e.g. differentiable rendering, single-view 3D prediction. The goal of this course is to explore this confluence of 3D Vision and Learning-based Methods.

16-890 Special Topic: Robot Cognition for Manipulation

Intermittent: 12 units
This seminar course will cover a mixture of modern and classical methods for robot cognition. We will review papers related to task planning and control using both symbolic and numeric methods. The goal of this course is to give students an overview of the current state of research on robot cognition.

16-891 Multi-Robot Planning and Coordination

Spring: 12 units
The course provides a graduate-level introduction to the field of multi-robot planning and coordination from both AI and robotics perspectives. Topics for the course include multi-robot cooperative task planning, multi-robot path/motion planning, learning for coordination, coordinating robots under uncertainty, etc. The course will particularly focus on state-of-the-art Multi-Agent Path Finding (MAPF) algorithms that can coordinate hundreds of robots with rigorous theoretical guarantees. Current applications for these technologies will be highlighted, such as mobile robot coordination for warehouses, drone swarm control, and multi-arm assembly. The course includes lectures, research paper presentations and discussions, and course projects.

16-892 Seminar: Multimodal Foundational Models

Fall: 12 units
This course will discuss recent foundation models proposed in the literature, with a focus on vision-language models. Topics include large language models, vision-language models, and vision-audio models. As time allows, this course will also discuss application of such models to visual, audio, and video content generation.
Prerequisite: 16-820

16-895 Understanding and Critiquing Generative Computer Vision

Spring: 12 units
In recent years, there have been significant advances in the field of large-scale generative modeling for visual data, such as DALL·E 2 and Stable Diffusion. This seminar course explores these advances beyond just reading and discussion. The goal is to not only inform state of the art but also develop critical and philosophical thinking among students. The course will involve reading papers, presentations, and discussions. The course will also involve reviewing and developing critical thinking.

16-901 RI-JEDI: Intro to Justice, Equity, Diversity, and Inclusion in Robotics

Fall and Spring: 3 units
This course will be offered in the first six weeks of the Fall semester, and will cover topics related to diversity, equity, and inclusion. This will be a companion course to CS-JEDI: 15-996. The course will be discussion-based and feature guest speakers. This course is offered to both graduate and undergraduate students in the RI. Designed specifically with the needs of PhD students in mind, the course is short, flexible, literature-based, framed through the lens of robotics and computer science, and is geared towards building community. We expect the students to spend and lt; 3 hours per week, almost all self-contained within the class time.

Tepper School of Business

Isabelle Bajeux-Besnainou, Dean

Oliver Hahl, Associate Dean, Undergraduate Programs

Jennifer Wegner, Assistant Dean, Undergraduate Programs

Location: Tepper Quad 2400
www.cmu.edu/tepper/programs (http://www.cmu.edu/tepper/programs/)

The Tepper School of Business prepares tomorrow's leaders who are innovative thinkers who thrive where data and humanity connect. Empowered with the latest technology, students and alumni apply human intelligence - analytical, creative, and emotional - to unleash data's insights and lead teams toward smarter decisions. The Tepper School of Business strives for excellence in the creation and dissemination of knowledge that is grounded in scientific principles and interdisciplinary collaboration, and is directed toward improving the practice and profession of management. Since its founding in 1949 by William Larimer Mellon, the Tepper School of Business at Carnegie Mellon has been a pioneer in the field of analytical decision-making and management science.

Today, the Tepper School is most recognized for research and teaching in the areas of economics, finance, marketing, operations management, organizational behavior, and operations research. The School's notable contributions to the intellectual community include nine Nobel laureates. It is also ranked among the schools with the highest rate of academic citations in the fields of finance, operations/production, operations research, and organizational behavior. Undergraduate and graduate students gain a valuable academic foundation in the fundamental disciplines of economics, the behavioral sciences and the management sciences. In addition to emphasizing an analytical approach to problem-solving and decision-making, students integrate communication, strategic thinking, and leadership into their student experience.

Educational Objectives

The Tepper School of Business is committed to excellence at all levels of education – undergraduate, graduate, executive, and life-long learning. We recognize that educational excellence does not occur in a vacuum: it is the result of an intentionally created environment that values and takes advantage of diversity of community, thought, and experience.

The Tepper School values a diverse and inclusive community because it enriches our experiences and leads to greater creativity and innovation in our decision making. Attracting an outstanding and diverse community of faculty, staff and students, and ensuring that all members of our community have a voice and sense of belonging, will empower them to strive for excellence.

Our goal of undergraduate educational excellence is grounded on four pillars:

- creating and providing innovative and dynamic curricula;
- challenging students with opportunities and experiences that encourage them to reflect on the intersections of ethics, responsibility, and professionalism – enabling them to develop the skills needed to be successful future leaders of teams and organizations;
- transforming the classroom experience to make use of technology-enhanced learning so that students have multiple and differentiated learning models; and
- collaborating with programs and colleges across the CMU campus to create unique synergistic curricular and co-curricular opportunities that take advantage of the breadth of CMU's excellence.

Academic Programs and Degrees Offered

The Tepper School offers degrees and programs that allow students to explore particular fields within their major.

- Bachelor of Science in Business Administration
- Bachelor of Science in Computational Finance
- Bachelor of Arts in Economics
- Bachelor of Science in Economics
- Bachelor of Science in Economics and Mathematics

The Dietrich College of Humanities and Social Sciences administers the joint economics majors.

- Bachelor of Science in Economics and Politics
- Bachelor of Science in Economics and Statistics

Minors, Additional Majors and Dual Degrees

In addition to offering majors, the Tepper School offers additional majors, dual degrees and minors to all members of the Carnegie Mellon undergraduate community. These degrees are:

- Additional Major in Business Administration
- Additional Major in Economics
- Minor in Business Administration
- Minor in Business Analytics and Optimization
- Minor in Economics
- Minor in Financial Management
- Minor in Innovation and Entrepreneurship
- Minor in Operations and Supply Chain Management
- Minor in Product Management
- Dual Degree in Business Administration
- Dual Degree in Economics

Students interested in these options should consult with Tepper Undergraduate Programs for academic advising.

Policies, Procedures and Opportunities

Academic Standing and Actions

The Tepper School believes that each student can be successful in their unique academic pursuits. The Tepper School is committed to partnering with students as they learn and grow. At the end of each semester, a student's academic progress and performance is reviewed to determine academic standing in the next academic semester. The academic actions support student success and create opportunities for students to reflect and utilize additional campus resources.

Academic Progress
In order to maintain good academic standing, Tepper students must attain at least a 2.0 minimum quality point average for each semester (as well as cumulatively), and also make and maintain adequate progress toward completing their degree requirements. For purposes of academic standing, default grades for incomplete grades are considered in QPA calculations. Adequate progress towards graduation means that students are successfully completing at least 80% of attempted units in a semester (calculated using total units carried when grades are entered). Grades of N, W, or R grade do not count as completed units.

Academic Concern (Departmental Status)
Students who are not making adequate progress toward the degree, demonstrated either through QPA or semester course load, will receive an academic concern notification. Receiving the letter of academic concern notifies students that they need to engage with their advisor to reflect on their academic performance, address their progress, and determine a plan for success. Students who receive a letter of academic concern are required to complete an Academic Success Plan with their advisor (instructions are included in the notification).

Students with academic concern status are reviewed by the Tepper School at the end of the semester. Students will return to good standing when they meet their academic concern expectations, earn at least a 2.0 semester QPA, complete at least 36 units, and earn a cumulative QPA at or above 2.0.

Academic Warning (Departmental Status)
Students with a semester QPA below 2.0 and/or did not earn at least 36 factorable units are reviewed for academic warning. Students with a cumulative QPA below 2.0 will also be placed on academic warning. When

a student is placed on academic warning, the Tepper School identifies expectations during the upcoming semester to support student success that must be met. Students on academic warning are required to complete an Academic Success Plan with their advisor (instructions are included in the notification). Students with academic warning status are not permitted to overload.

Students with academic warning status are reviewed by the Tepper School at the end of the semester. Students will return to good standing when they meet their academic warning expectations, earn at least a 2.0 semester QPA, complete at least 36 units, and earn a cumulative QPA at or above 2.0.

Academic Suspension (University Status, Department Decision)
Students who do not meet their academic warning requirements may receive a one-year academic suspension. When a student is academically suspended, the Tepper School remains committed to student success and works with students on academic suspension throughout the time period to ensure a successful return and sustained recovery during their CMU career. When a student is placed on academic suspension, they must meet with their academic advisor and the assistant dean to develop a plan for their future success. While on academic suspension, there are impacts (https://www.cmu.edu/hub/registrar/leaves-and-returns/impacts.html) for students to be aware of while away from their CMU studies.

To return from academic suspension, the Tepper School requires the student to submit material for review to determine a student's eligibility to return. Information about the materials required to return from academic suspension and the deadline for submission are communicated within the academic actions letter. (University Suspension Policy (https://www.cmu.edu/policies/student-and-student-life/suspension-required-withdrawal-policy.html))

Final Academic Warning (Departmental Status)
Following an academic suspension, Tepper School students return on final academic warning. When a student is placed on final academic warning, conditions are identified during the final academic warning semester that must be met to support student success. Students on final academic warning are required to complete an Academic Success Plan with their advisor (instructions are included in the notification) and follow additional conditions outlined by the Tepper School. Students with final academic warning status are reviewed by the Tepper School at the end of the semester. Failure to meet final academic warning conditions may lead to an academic drop from the Tepper School.

Drop (University Status)
Drop means permanent separation from the Tepper School. This follows a student's failure to meet minimal academic performance while on final academic warning following academic suspension.

Appeals
Students have the right to appeal their academic status decision to the Tepper School Dean or their appointed designee. All appeals must be received in writing by ten business days from the date of the academic standing communication. If the first appeal is denied by the Tepper School and the student wishes to further appeal the decision to the Provost Office, there are five business days from the date of the Dean's communication to submit the appeal. Additional information about appealing an academic action decision is found in The Word: Student Handbook (https://www.cmu.edu/student-affairs/theword/academic/appeal-of-grades-and-academic-actions.html).

COURSE DOUBLE COUNTS

Students cannot double count courses within the major's curriculum. When students pursue a minor, additional major, and/or dual degree, the double-count policies are determined by the academic department responsible for the minor, additional major, and/or dual degree.

For business majors, courses in the concentration and business elective requirements are not allowed to double count against any other degree requirement, including minor or additional major pursuits.

Non-Tepper students earning a minor, additional major, or dual degree in the Tepper School must adhere to the Tepper policies listed in the catalog for double counting courses. There are no double-counting restrictions between the minor, additional major, or dual degree and the student's home college general education requirements.

COURSE GRADE POLICIES

Students must earn letter grades (A through D) for required degree courses. The only degree requirement wherein a P grade is permitted is Core @ Carnegie Mellon (99-101) or P grades awarded in the Spring 2020 Special Pass/No Pass election. Repeating courses does not replace the previously earned grade on the transcript and both grades are calculated into the QPA. Courses completed with a letter grade earn factorable units that are used to compute QPA.

DEAN'S LIST

Tepper students who earn at least a 3.75 QPA with at least 36 factorable units (while receiving no Incomplete grades) receive Dean's List honors. The Dean's List is published on the Tepper School website and honors are awarded at the end of the fall and spring semesters.

DUAL DEGREE

To earn a dual degree, students must complete a minimum of 90 units for the dual degree in addition to the units required for their primary degree. Students must also complete both sets of general education requirements.

Tepper students interested in pursuing a dual degree should discuss their plans with the academic department offering the dual degree. Students must meet all requirements for both the dual degree and the Tepper degree (including concentration requirement for business majors). The student's dual degree will substitute for the primary major's minor requirement provided it is completed prior to or at the same time as the primary degree.

Non-Tepper students intending to pursue a Tepper School dual degree are required to apply for the dual degree and encouraged to consult with the assistant dean about their interests and application process. Students must meet all requirements for the Tepper major including the University Core (and concentration requirement for business dual degree). The student's primary degree will substitute for the dual degree's minor requirement provided it is completed prior to or at the same time as the dual degree.

EXTERNAL TRANSFER CREDIT

Courses taken at higher education institutions outside of Carnegie Mellon can be considered for transfer credit through the Tepper School course equivalency process. Students must earn a final grade of C- or higher to receive transfer credit unless otherwise noted by an individual approval. CMU Washington Semester and CMU-Qatar courses are exempt from the transfer course policy; community college and online courses may be considered for transfer credit by the individual department policies. Students pursuing a Tepper School dual degree are subject to the transfer policy for primary majors.

The following courses must be taken at Carnegie Mellon: 70-106 (http://coursecatalog.web.cmu.edu/search/?P=70-106) Business Science, 70-104 (http://coursecatalog.web.cmu.edu/search/?P=70-104) Business Leadership Endeavor I, 70-204 (http://coursecatalog.web.cmu.edu/search/?P=70-204) Business Leadership Endeavor II, 70-304 (http://coursecatalog.web.cmu.edu/search/?P=70-304) Business Leadership Endeavor III, 70-401 (http://coursecatalog.web.cmu.edu/search/?P=70-401) Management Game or equivalent, 99-101 (http://coursecatalog.web.cmu.edu/search/?P=99-101) Core @ Carnegie Mellon, and First Year Writing.

Students pursuing the business major can transfer up to 90 units from higher education institutions to count towards the degree requirements, including study abroad:

- Only 5 courses can be taken at U.S. institutions;
- Only 3 courses can transfer as general education courses;
- Only 2 courses for the business major can transfer to the business foundation courses requirements;
- Only 1 course for the business major can transfer between the concentration and business elective course requirements;
- Only 1 course for the business major can transfer to the business core course requirements;

For economics majors a maximum of 18 units of economics elective course credit can transfer for the BA or BS in Economics and a maximum of 9 units of economics elective course credit can transfer for the BS in Economics and Mathematics.

Students who complete dual enrollment college coursework during high school must be able to produce a university/college transcript and demonstrate that the course was offered with the same level of instruction. Dual enrollment courses must be evaluated within the CMU equivalency processes and the courses must fall within the current transfer policy. External transfer students admitted to the Tepper School may transfer up to 182 units (including AP credit). External transfer students are not permitted to earn additional transfer credit up to 27 units (exceptions considered for study abroad).

Non-UBA students interested in pursuing a Tepper minor/additional major can transfer no more than:

- 9 units toward a business minor;
- 27 units toward the business additional major;
- 18 units toward the economics minor/additional major.

GRADUATION REQUIREMENTS AND PARTICIPATION

In order to graduate, students must meet all course requirements specified for the major, earn a 2.00 or higher cumulative QPA, and complete the required number of earned factorable units. Students must also meet all university residence requirements and all university financial obligations before being awarded the degree and diploma. Students with less than 36 units remaining to complete in their undergraduate degree requirements are eligible to participate in graduation events. In this situation, students participate in the event but do not receive their degree and diploma until all degree requirements, university residence requirements, and financial obligations are met.

Students qualify to graduate by meeting the following conditions:

1. Complete all degree, College, and University course requirements as shown in the course catalog.
2. Receive recommendation for their degree by the faculty of the Tepper School.
3. Meet the University's residency requirement, detailed in the Undergraduate Academic Regulations (p. 25) section of the catalog.
4. Meet all financial obligations to the university before being awarded a degree.

Modification of Graduation Requirements: A student may petition to modify graduation requirements to the Assistant Dean.

Honors Thesis for Primary and Additional Majors

The Tepper School grants College Honors to graduating students who complete a senior honors thesis. The thesis is a two-semester research project with a written thesis as a final product and a presentation at the University’s Meeting of the Minds research symposium in May. Eligible students must have at least 75% of their undergraduate course units completed. The honors thesis is 18 units in total and students receive College Honors upon graduation. Non-Tepper students pursuing the Tepper additional majors may apply for the Tepper School’s College Honors.

Independent Study

The Tepper School supports student research and selective experiential learning experiences through credit-earning independent study with CMU faculty members. Students must be in good academic standing to be eligible for independent study. Students can earn between three and nine units of independent study for a factorable grade. The nine units are agnostic to which department awards them unless the Independent Study units are a requirement for a minor or additional major. Independent study cannot be used as a substitute for an existing course in the undergraduate catalog and cannot be a substitute for a curriculum requirement.

All independent study plans require the active involvement of a CMU faculty advisor who is responsible for the course structure and content activities, evaluation criteria, and final grade determination. Only one independent study is applied to the degree requirements. The independent study application must be received by or on the add deadline of the semester during which the study is anticipated.

Integrated and Accelerated Master’s Degree (3-1-1 program)

Integrated and Accelerated Master’s Degree programs enable undergraduate students to earn both an undergraduate degree and a masters degree by remaining one additional year at Carnegie Mellon. Students attain further breadth and/or depth of knowledge in their area of study, broadening their post-graduation career opportunities. These opportunities exist across various Carnegie Mellon academic units.

The Tepper School of Business offers an integrated and accelerated Master of Business Administration (MBA) to CMU undergraduate students completing either a Business Administration major or an additional major in Business Administration. Students complete 3 years as a CMU undergraduate, followed by 1 year of integrated undergraduate and graduate study, followed by 1 full year of graduate MBA coursework at Tepper. This allows students to complete the two degrees within 5 years.

To be admitted to the program, students must have applicable work or internship experience and have attained grades of B or higher in the following courses: 70-257, 21-257 or 21-292; 73-102 or 73-104; 70-122; 70-371; 70-381; and 70-391.

Students should apply during their junior year for admission to the Tepper MBA. Additional information about the Tepper MBA admission requirements is available on the Tepper School website (https://www.cmu.edu/tepper/programs/mba/admissions/).

Leave of Absence

The Tepper School is committed to each student’s success as they progress through the degree requirements. There may be times when it is in the student’s best interest to consider a Leave of Absence in consultation with their academic advisor. When a student elects a Leave of Absence, the Tepper School remains committed to student success and works with the student throughout the time away in targeted ways to ensure a successful return to CMU. W grade assignments are assigned depending on the circumstances and timing of the Leave of Absence. Students preparing to return from a Leave of Absence will work with the Assistant Dean and academic advisor to submit the required University paperwork and prepare for a successful return.

MINOR REQUIREMENT FOR Tepper STUDENTS & ADDITIONAL MAJOR OPTION

Students are required to complete a minor to earn a BS in Business Administration or BS/BA in Economics degree; some students choose to fulfill this requirement with an additional major. Because each department has its own process for declaring a minor/additional major, students should contact the individual department for specific policies. Upon official declaration of the minor/additional major, students should regularly meet with the minor/additional major advisor and their Tepper School primary advisor to ensure that they are meeting the requirements of the minor/additional major. If a student completes an additional major, the minor requirement is waived (as is the concentration requirement for business majors). The minor/additional major is certified by the corresponding department at the time of graduation. Failure to complete the minor requirement will prevent a student from graduating.

Business students must complete at least 27+ units of business elective courses in lieu of a concentration if they earn an additional major.

PASS GRADES

There is a limit of 9 units of “P” that students may apply toward the total units needed for a Tepper degree (this excludes Core @ CMU). Exceptions are available for students who earned P grades during Spring 2020.

SEMESTER COURSE OVERLOAD

A course overload for a Tepper student is any schedule with more than 51 units in Fall or Spring semester. Students must petition to receive a semester overload. For Fall and Spring semesters, Tepper students petition to enroll in more than 51 units for the semester to total 57 units. Students must meet the identified QPA to petition for an overload. Petitions are reviewed and determined by the Tepper School. Students transferring into the Tepper School from across campus may be required to reduce their unit load to meet the Tepper School policy of 51 units per semester. New first-year or external transfer students are restricted to 50 units in their first semester and are not eligible to overload until they complete one semester. A student may lose the right to overload if their QPA drops below the threshold after an overload for the next semester has been granted.

Student Defined Major

Carnegie Mellon offers the opportunity for undergraduate students to pursue a University Student-Defined Major (http://coursecatalog.web.cmu.edu/aboutcmu/undergraduateoptions/#studentdefinedmajortextcontainer) (SDM). Students interested in this opportunity should begin by speaking with the Assistant Dean. The Tepper School requires students pursuing the SDM to be in good academic standing at the time the SDM is approved by Tepper as the home college.

Study Abroad

Tepper students have an array of study abroad programs available to them. Tepper offers Departmental Exchange Programs (https://www.cmu.edu/tepper/programs/undergraduate-business/curriculum/study-abroad.html) with business schools abroad, and many other options can be explored through CMU's Study Abroad Portal (https://cmu-sa.terradotta.com/). Students interested in study abroad programs should consult with a study abroad advisor in the Office of International Education and their academic advisor about the location, courses to study, and appropriate timing. Some study abroad programs have specific QPA requirements that must be met; for programs without a defined QPA requirement, the Tepper School requires students to have a cumulative QPA of 2.0 or higher to pursue a study abroad experience.

Students work with the Office of International Education (https://www.cmu.edu/studyabroad/) to complete the Study Abroad Transfer Credit (SATC) Form, which is required for all CMU students, prior to departure. Students must have their courses reviewed for equivalency through the transfer credit review process and study abroad transfer credit must align with transfer credit policies. If course plans change, the student must update the SATC form.

Tepper Minors

The Tepper School offers minors in Business Administration, Business Analytics and Optimization, Economics, Financial Management, Operations and Supply Chain Management, Product Management, and Innovation & Entrepreneurship (as an IDeATE minor). Eligibility to declare one of these minors varies and students should consult the catalog for additional declaration information. Students enrolled in one of these minors adhere to the same grading policies as primary majors. This includes the minimum QPA, letter grades for degree required courses, and repeat courses. Upon completion of the minor degree requirements, the Tepper School certifies the minor and it is recorded on the academic transcript; minors do not appear on a student's diploma per University policy.

If a student is pursuing a business or economics minor that requires 73-102 or 73-104 and receives a prerequisite waiver for 73-102, 9 additional units of minor elective coursework is required to ensure 54+ units are met in the minor curriculum.

For non-business students who completed 70-106 as a primary business major and subsequently pursue the business administration minor, 70-106 can substitute for 70-100. 70-106 is not an allowed substitute in any other circumstance.

Students majoring in Mathematics with a concentration in Operations Research who elect to pursue a business administration minor must take an additional constrained elective unique to the minor to avoid a violation of the double-count policy.

TRANSFERRING INTO BUSINESS

The Tepper School accepts applications for external transfer admission from any academic institution outside of Carnegie Mellon University on a limited basis. Students interested in transfer should contact Carnegie Mellon's Office of Admission.

Tepper also accepts applications for a major change from current Carnegie Mellon students who are in other academic programs to begin in either the fall or spring semester. The application requires a resume and personal statement. CMU students interested in changing to a Tepper major must complete the internal transfer application by the deadline which is always the last day of class in the fall or spring semester preceding the desired semester for transfer.

To be considered for the business major, a student must have successfully completed a Carnegie Mellon math course required in the business program (21-120 Differential and Integral Calculus, 21-256 Multivariate Analysis, 21-254 Linear Algebra and Vector Calculus for Engineers, or21-259 Calculus in Three Dimensions), and 73-102 Principles of Microeconomics or 73-104 Principles of Microeconomics Accelerated, and 70-122 Introduction to Accounting.

To be considered for an economics major, a student must have successfully completed a Carnegie Mellon math course required in the economics program (21-256 Multivariate Analysis, 21-254 Linear Algebra and Vector Calculus for Engineers, or 21-259 Calculus in Three Dimensions), 73-102 Principles of Microeconomics or 73-104 Principles of Microeconomics Accelerated, and 73-103 Principles of Macroeconomics.

Faculty

Full-Time Faculty

- MUSTAFA AKAN, Associate Professor of Operations Management – Ph.D., Northwestern University; Carnegie Mellon, 2008–
- JAMES F. ALBERTUS, Assistant Professor of Finance – Ph.D., New York University; Carnegie Mellon, 2016–
- LAURENCE ALES, Senior Associate Dean of Education; Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2008–
- SEAN AMMIRATI, Distinguished Service Professor of Entrepreneurship – B.S. Computer Information Systems, Grove City College; Carnegie Mellon, 2002–
- JAY APT, Professor Emeritus – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2000–
- LINDA ARGOTE, Thomas Lord Professor of Organizational Behavior and Theory – Ph.D., University of Michigan; Carnegie Mellon, 1979–
- BRANDY L. AVEN, Associate Professor of Organizational Theory, Strategy, and Entrepreneurship – Ph.D., Stanford University; Carnegie Mellon, 2010–
- ISABELLE BAJEUX-BESNAINOU, Dean; Richard P. Simmons Professor of Finance – Ph.D. , University of Paris; Carnegie Mellon, 1989–
- JAMES A. BEST, Assistant Professor of Economics – Ph.D., University of Edinburg; Carnegie Mellon, 2018–
- CARLA BEVINS, Associate Teaching Professor of Business Communication – Ph.D., University of Kentucky; Carnegie Mellon, 2017–
- RIMA BHATTACHARYAY, Assistant Teaching Professor of Strategy – Ph.D., McGill University; Carnegie Mellon, 2024–
- ROBERT BLATTBERG, Timothy W. McGuire Distinguished Service Professor of Marketing – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1971–
- PATRICK BLONIEN, Instructor of Finance – Ph.D., Rice University; Carnegie Mellon, 2024–
- PETER BOATWRIGHT, Allan D. Shocker Professor of Marketing and New Product Development; Co-Director, Integrated Innovation Institute – Ph.D., University of Chicago; Carnegie Mellon, 1997–
- PIETRO BONALDI, Assistant Professor of Accounting – Ph.D., University of Chicago; Carnegie Mellon, 2017–
- ARTHUR BONI, The John R. Thorne Distinguished Career Professor of Entrepreneurship, Emeritus – Ph.D., University of California, San Diego; Carnegie Mellon, 1995–
- SERRA BORANBAY-AKAN, Associate Teaching Professor of Economics – Ph.D., Northwestern University; Carnegie Mellon, 2013–
- CLARA BURKE, Associate Teaching Professor of Business Communication – Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 2015–
- GUILLERMO G. CALIENDO, Associate Teaching of Business Communication – Ph.D., University of Pittsburgh; Carnegie Mellon, 2024–
- MING MING CHAPMAN, Distinguished Service Professor of Design – M.A., University of London; Carnegie Mellon, 2024–
- SOO-HAENG CHO, IBM Professor of Operations Management – Ph.D., University of California, Los Angeles; Carnegie Mellon, 2008–
- ROSALIND M. CHOW, Associate Professor of Organizational Behavior and Theory – Ph.D., Stanford University; Carnegie Mellon, 2008–
- MATTIA CIOLLARO , Assistant Teaching Professor of Business Analytics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2022–
- TAYA R. COHEN, Professor of Organizational Behavior and Business Ethics – Ph.D., University North Carolina, Chapel Hill; Carnegie Mellon, 2010–
- BENJAMIN COLLIER, Assistant Teaching Professor of Business Analytics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2012–
- GERARD CORNUÉJOLS, IBM University Professor of Operations Research, Emeritus – Ph.D., Cornell University; Carnegie Mellon, 1978–
- ROBERT DALTON, Associate Teaching Professor of Economics, Emeritus – Ph.D., University of Missouri; Carnegie Mellon, 1985–
- ROBERT M. DAMMON, Richard C. Green Professor of Financial Economics; Emeritus – Ph.D., University of Wisconsin, Madison; Carnegie Mellon, 1984–
- EMILY DEJEU, Assistant Teaching Professor of Business Communication – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2022–
- MATTHEW DENES, Assistant Professor of Finance and Entrepreneurship – Ph.D., University of Washington; Carnegie Mellon, 2017–
- ABBE DEPRETIS, Assistant Teaching Professor of Business Communication – Ph.D., University of Maryland; Carnegie Mellon, 2017–

- TIMOTHY P. DERDENGER, Associate Professor of Marketing and Strategy – Ph.D., University of Southern California; Carnegie Mellon, 2009–
- EMILY DIANA, Assistant Professor of Operations Research – Ph.D., University of Pennsylvania; Carnegie Mellon, 2024–
- LINDA DU, Instructor of Finance – Ph.D., University of Texas at Austin; Carnegie Mellon, 2024–
- KENNETH B. DUNN, Professor of Financial Economics, Emeritus – Ph.D., Purdue University; Carnegie Mellon, 1979–
- TIM EDERER, Assistant Professor of Economics – Ph.D., Toulouse School of Economics; Carnegie Mellon, 2024–
- DENNIS N. EPPLE, Thomas Lord University Professor of Economics – Ph.D., Princeton University; Carnegie Mellon, 1974–
- SELMAN EROL, Assistant Professor of Economics – Ph.D., University of Pennsylvania; Carnegie Mellon, 2017–
- MARK FICHMAN, Associate Professor of Organizational Behavior and Theory, Emeritus – Ph.D., University of Michigan; Carnegie Mellon, 1980–
- CHRISTINA FONG, Research Scientist, Department of Social and Decision Sciences, Dietrich College – Ph.D., University of Massachusetts; Carnegie Mellon, 2000–
- MOHSEN FOROUGHIFAR, Assistant Professor of Business Technologies – Ph.D., University of Toronto; Carnegie Mellon, 2023–
- JEFFREY GALAK, Associate Professor of Marketing – Ph.D., New York University; Carnegie Mellon, 2009–
- JOHN GASPER, Associate Teaching Professor of Economics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2008–
- BRENT GLOVER, Associate Professor of Finance – Ph.D., University of Pennsylvania; Carnegie Mellon, 2011–
- EVELYN XIAO GONG, Assistant Professor of Operations Management – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2023–
- DAVID GOYETTE, Associate Teaching Professor of Business Communication and Acting – M.F.A., The University of Texas at Austin; Carnegie Mellon, 2023–
- MEREDITH GRELLI, Assistant Teaching Professor of Entrepreneurship – MBA, Carnegie Mellon University; Carnegie Mellon, 2022–
- OLIVER HAHL, Associate Dean of Undergraduate Programs; Assistant Professor of Organizational Behavior and Strategy – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2013–
- DALE HERSHEY, Associate Teaching Professor of Law, Emeritus – LL.B., Harvard Law School; Carnegie Mellon, 1987–
- GEOFFREY HITCH, Associate Teaching Professor of Acting and Business Communication, Emeritus – M.F.A., Carnegie Mellon; Carnegie Mellon, 1992–
- BURTON HOLLIFIELD, PNC Professor of Finance; Professor of Financial Economics – Ph.D., Carnegie Mellon; Carnegie Mellon, 1998–
- JOHN HOOKER, T. Jerome Holleran University Professor of Business Ethics and Social Responsibility; Professor of Operations Research, Emeritus – Ph.D., Vanderbilt University; University of Tennessee; Carnegie Mellon, 1984 –
- YAN HUANG, Associate Professor of Business Technologies – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2018–
- RUBAB JAFRY-O'CONNOR, Distinguished Service Professor of Management – Ed.D., University of Pittsburgh; Carnegie Mellon, Carnegie Mellon 2019–
- JIM JEN, Distinguished Service Professor of Entrepreneurship – M.B.A., Stanford University; Carnegie Mellon, 2023–
- ZHAOHUI (ZOEY) JIANG, Assistant Professor of BusinessTechnologies – Ph.D., University of Michigan; Carnegie Mellon, 2020–
- JOSEPH B. KADANE, Leonard J. Savage University Professor of Statistics and Social Sciences, Emeritus – Ph.D., Stanford University; Carnegie Mellon, 1969–
- SHAM KEKRE, Distinguished Service Professor of Operations Management – Ph.D., University of Rochester; Carnegie Mellon, 1984–
- SUNDER KEKRE, Vasantrao Dempo Professor; Professor of Operations Management; Academic Director Executive Education – Ph.D., University of Rochester; Carnegie Mellon, 1984–
- ROBERT KELLEY, Distinguished Service Professor of Organizational Behavior and Theory – Ph.D., Colorado State University; Carnegie Mellon, 1977–
- FATMA KILINC-KARZAN, Professor of Operations Research – Ph.D., Georgia Institute of Technology; Carnegie Mellon, 2011–
- MINKYUNG KIM, Assistant Professor of Marketing – Ph.D., Yale University; Carnegie Mellon, 2023–
- TAE WAN KIM, Associate Professor of Business Ethics; Xerox Junior Faculty Chair – Ph.D. , University of Pennsylvania; Carnegie Mellon, 2012–
- DAVID KRACKHARDT, Professor of Organizations, H. John Heinz III College and Joint Appointment at Tepper School of Business – Ph.D., University of California, Irvine; Carnegie Mellon, 1991–
- ROBERT E. KRAUT, Herbert A. Simon Professor of Human-Computer Interaction, Emeritus, School of Computer Science and Joint Appointment at Tepper School of Business – Ph.D., Yale University; Carnegie Mellon, 1993–
- LARS-ALEXANDER KUEHN, Associate Professor of Finance – Ph.D., University of British Columbia; Carnegie Mellon, 2008–
- ALEXEY KUSHNIR, Assistant Professor of Economics – Ph.D., Pennsylvania State University; Carnegie Mellon, 2014–
- FINN KYDLAND, The Richard P. Simmons Distinguished Professorship; University Professor of Economics; Emeritus; Nobel Laureate (2004) – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1977–
- DAVID L. LAMONT, Associate Teaching Professor; Director, Management Games – M.S.I.A., Carnegie Mellon University; Carnegie Mellon, 1984–
- DEREK LEBEN, Associate Teaching Professor of Business Ethics – Ph.D., Johns Hopkins University; Carnegie Mellon, 2012–
- JUAN RIVERA LEBRON, Assistant Professor of Marketing – M.F.A., University of Idaho; Carnegie Mellon, 2022–
- SUNKEE LEE, Associate Professor of Organizational Theory and Strategy – Ph.D., INSEAD; Carnegie Mellon, 2017–
- REBECCA LESSEM, Associate Professor of Economics – Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 2011–
- ANDREW A. LI, Assistant Professor of Operations Research – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2018–
- PIERRE JINGHONG LIANG, Professor of Accounting – Ph.D., University of Florida; Carnegie Mellon, 1998–
- YUCHENG LIANG, Assistant Professor of Accounting – Ph.D., Stanford Graduate School of Business; Carnegie Mellon, 2020–
- TONG (JOY) LU, Assistant Professor of Marketing – Ph.D., University of Pennsylvania; Carnegie Mellon, 2018–
- CRAIG MARKOVITZ, Distinguished Service Professor of Entrepreneurship; Entrepreneur-in-Residence, Swartz Center – MBA, DePaul University; Carnegie Mellon, 2017–
- JOHN H. MATHER, Teaching Professor of Marketing, Emeritus – Ph.D., University of Arizona; Carnegie Mellon, 1992–
- DAVID S. MAWHINNEY, Teaching Professor of Entrepreneurship; Executive Director of the Swartz Center for Entrepreneurship; Executive Director, Donald H. Jones Center for Entrepreneurship – MBA, Carnegie Mellon University; Carnegie Mellon, 2011–
- SIMON MAYER, Assistant Professor of Finance – Ph.D., Erasmus University Rotterdam and Tinbergen Institute; Carnegie Mellon, 2023–
- ROBERT M. MILLER, Richard M. Cyert and Morris DeGroot Professorship in Economics and Statistics; Professor of Economics and Strategy – Ph.D., University of Chicago; Carnegie Mellon, 1982–
- ROBERT T. MONROE, Teaching Professor of Business Technologies; Director, Part-Time Online Hybrid MBA Program – Ph.D., Carnegie Mellon; Carnegie Mellon, 2004–
- ALAN MONTGOMERY, Professor of Marketing; Executive Director, Center for Marketing Technology and Information; Head, Ph.D. Program – Ph.D., University of Chicago; Carnegie Mellon, 1999–
- BENJAMIN MOSELEY, Associate Professor of Operations Research – Ph.D., University of Illinois; Carnegie Mellon, 2018–
- D. CARRINGTON MOTLEY, inAssistant Professor of Organization Theory and Entrepreneurship – Ph.D., Stanford University; Carnegie Mellon, 2022–
- TRIDAS MUKHOPADHYAY, Deloitte Consulting Professor of e-Business; Professor of Business Technologies – Ph.D., University of Michigan; Carnegie Mellon, 1986–
- NICHOLAS Z. MULLER, Professor of Economics, Engineering, and Public Policy (joint with the Department of Engineering and Public Policy, College of Engineering; Lester and Judith Lave Development Chair in Economics, Engineering and Public Policy – Ph.D., Yale University; Carnegie Mellon, 2017–
- MELISSA MURPHY, Distinguished Service Professor of Marketing – M.A., Northwestern University; Carnegie Mellon, 2020–
- MILDRED S. MYERS, Teaching Professor of Business Management Communication, Emerita – D.A., Carnegie Mellon University; Carnegie Mellon, 1984–
- ANH NGUYEN, Assistant Professor of Economics – Ph.D., Columbia University; Carnegie Mellon, 2018–
- JEAN OH, ssistant Professor of Organizational Theory and Entrepreneurship – Ph.D., Columbia University; Carnegie Mellon, 2024–
- JOHN R. O'BRIEN, Associate Professor of Accounting and Experimental Economics, Emeritus – Ph.D., University of Minnesota; Carnegie Mellon, 1984 –

- CHRISTOPHER OLIVOLA, Associate Professor Marketing – Ph.D., Princeton University; Carnegie Mellon, 2013–
- ANIKO ÖRY, Associate Professor of Economics – Ph.D., University of California; Carnegie Mellon, 2023–
- CHRISTOPHER PEACE, Assistant Teaching Professor of Business Communication – Ph.D., University of Kansas; Carnegie Mellon, 2024–
- JAVIER F. PENA, Bajaj Family Chair in Operations Research – Ph.D., Cornell University; Carnegie Mellon, 1999–
- EVELYN M. PIERCE, Teaching Professor of Teaching Professor of Business Management Communication, Emeritus – M.F.A., University of Pittsburgh; Carnegie Mellon, 1993–
- RONALD PLACONE, Associate Teaching Professor of Business Communications; Emeritus – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2012–
- R. RAVI, Andris A. Zoltners Professor of Business; Professor of Operations Research and Computer Science; Director of Analytics Strategy – Ph.D., Brown University; Carnegie Mellon, 1995–
- MAX W. RISCH, Assistant Professor of Accounting – Ph.D., University of Michigan; Carnegie Mellon, 2020–
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- DIANE RULKE, Distinguished Service Professor of Organizational Behavior and Theory – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2023–
- BRYAN R. ROUTLEDGE, Associate Professor of Finance – Ph.D., University of British Columbia; Carnegie Mellon, 1995–
- MARYAM SAEEDI, Assistant Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2012–
- ALAN SCHELLER-WOLF, Richard M. Cyert Professor of Operations Management – Ph.D., Columbia University; Carnegie Mellon, 1996–
- DUANE J. SEPPI, Senior Associate Dean, Faculty;Richard C. Green Professor of Financial Economics – Ph.D., University of Chicago; Carnegie Mellon, 1986–
- CATHERINE SHEA, Assistant Professor of Organizational Behavior and Theory – Ph.D., Duke University; Carnegie Mellon, 2017–
- LIYAN SHI, Assistant Professor of Economics – Ph.D., University of California, Los Angeles; Carnegie Mellon, 2018–
- ALI SHOURIDEH, Assistant Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2012–
- KARAN SINGH, Assistant Professor of Operations Research – Ph.D., Princeton University; Carnegie Mellon, 2021–
- PARAM VIR SINGH, Associate Dean of Research; Carnegie Bosch Professor of Business Technologies – Ph.D., University of Washington, Seattle; Carnegie Mellon, 2008–
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- FALLAW B. SOWELL, Associate Professor of Economics, Emeritus – Ph.D., Duke University; Carnegie Mellon, 1988–
- CHESTER S. SPATT, Pamela R. and Kenneth B. Dunn Professor of Finance – Ph.D., University of Pennsylvania; Carnegie Mellon, 1979–
- STEPHEN E. SPEAR, Professor of Economics – Ph.D., University of Pennsylvania; Carnegie Mellon, 1982–
- KANNAN SRINIVASAN, H. J. Heinz II Professor of Management, Marketing, and Information Systems – Ph.D., University of California, Los Angeles; Carnegie Mellon, 1986–
- ANTHONY P. STANTON, Teaching Professor of Graphic Media Management, Emeritus – Ph.D., University of Pittsburgh; Carnegie Mellon, 1996–
- PETER STUETTGEN, Associate Teaching Professor of Marketing – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2019–
- AUSTIN SUDBURY, Associate Teaching Professor of Accounting – Ph.D., Ohio State University; Carnegie Mellon, 2014–
- ANDRÉ SZTUTMAN, Assistant Professor of Economics – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2023–
- SRIDHAR R. TAYUR, The Ford Distinguished Research Chair; University Professor of Operations Management – Ph.D., Cornell University; Carnegie Mellon, 1991–
- CHRISTOPHER I. TELMER, Associate Professor of Financial Economics – Ph.D., Queen's University at Kingston (Canada); Carnegie Mellon, 1992–
- MICHAEL A. TRICK, Dean, Carnegie Mellon University, Qatar; Harry B. and James H. Higgins Professor of Operations Research – Ph.D., Georgia Institute of Technology; Carnegie Mellon, 1988–
- MARIA TOMPROU, Assistant Teaching Professor of Organizational Behavior and Theory – Ph.D., Athens University of Economics and Business; Carnegie Mellon, 2009–
- DAVID E. TUNGATE, Distinguished Service Professor of Law – LL.B., University of Illinois School of Law; Carnegie Mellon, 1991–
- WILLEM-JAN VAN HOEVE, Carnegie Bosch Professor of Operations Research – Ph.D., University of Amsterdam; Carnegie Mellon, 2007–
- BETH WALTER, Associate Teaching Professor of Business Communication – Ph.D., Duquesne University; Carnegie Mellon, 2014–
- LAURIE R. WEINGART, Interim Associate Dean of Masters Programs; Richard M. and Margaret S. Cyert Professor of Organizational Behavior and Theory – Ph.D., Northwestern University; Carnegie Mellon, 1989–
- ANITA WILLIAMS WOOLLEY, Professor of Organizational Behavior and Theory – Ph.D., Harvard University; Carnegie Mellon, 2008–
- ERINA YTSMA, Assistant Professor of Accounting – Ph.D., London School of Economics; Carnegie Mellon, 2018–
- RICHARD O. YOUNG, Teaching Professor of Business Communication, Emeritus – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1984–
- ARIEL ZETLIN-JONES, Associate Professor of Economics – Ph.D. , University of Minnesota; Carnegie Mellon, 2012–
- GAOQING ZHANG, Associate Professor of Accounting – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2023–

Courtesy

- KATHLEEN CARLEY, Professor of Computation, Organization and Society, Institute for Software Research and by courtesy, Tepper School of Business
- KAREN CLAY, Professor of Economics and Public Policy, Heinz College, and by courtesy, Tepper School of Business – Ph.D., Stanford University; Carnegie Mellon, 1994–
- VINCENT CONITZER, Professor of Computer Science, School of Computer Science, and by courtesy, Tepper School of Business
- MARTIN GAYNOR, E.J. Baron University Professor of Economics and Public Policy, Heinz College, and by courtesy, Tepper School of Business – Ph.D., Northwestern University; Carnegie Mellon, 1995–
- MOR HARCHOL-BALTER, Professor of Computer Science, School of Computer Science, and by courtesy, Tepper School of Business – Ph.D., University of California at Berkeley; Carnegie Mellon, 1996–
- AKSHAYA JHA, Assistant Professor of Economics and Public Policy, Heinz College, and by courtesy, Tepper School of Business
- DANIEL NAGIN, Teresa and H. John Heinz III University Professor of Public Policy and Statistics, Heinz College and by courtesy, Tepper School of Business
- STEPHEN ROEHIG, Teaching Professor of Information Systems, Heinz College, and by courtesy, Tepper School of Business
- STEVEN SHREVE, University Professor of Mathematical Sciences; Orion Hoch Professor of Mathematical Sciences, Mellon College of Science, and by courtesy, Tepper School of Business, Emeritus – Ph.D., University of Illinois; Carnegie Mellon, 1977–
- RAUL TELANG, Professor of Information Systems, Heinz College, and by courtesy, Tepper School of Business – Ph.D., Carnegie Mellon University;

Visiting Faculty

- DEEPAK AGRAWAL, Visiting Assistant Professor of Operations Management – Ph.D., Stanford University; Carnegie Mellon, 2024–
- LUCAS BOLTE, Post Doctoral Fellow in Economics – Ph.D., Stanford University; Carnegie Mellon, 2024–

Adjunct Faculty

- MICHAEL ALLERUZZO, Adjunct Professor of Management
- GERARD BEENEN, Adjunct Professor of Organizational Behavior and Theory
- STEVEN BOLLINGER, Adjunct Professor of Entrepreneurship
- LEONARD CARIC, Adjunct Professor of Entrepreneurship
- L. FRANK DEMMLER, Adjunct Professor of Entrepreneurship
- CLIFFORD EARLY, Adjunct Professor of Law
- JIM FOSTER, Adjunct Professor of Finance
- MAX FRIEDMAN, Adjunct Professor of Product Management
- ALEX GRELLI, Adjunct Professor of Entrepreneurship
- JOSEPH HORNACK, Adjunct Professor of Law
- WILLIAM KAIGLER, Adjunct Professor of Entrepreneurship
- NICK PRETNAR, Adjunct Professor of Economics
- ISAAC RUDICH, Adjunct Professor of Operations Management
- AARON TAINTER, Adjunct Professor of Entrepreneurship

- COURTNEY WILLIAMSON, Adjunct Professor of Entrepreneurship
- JJ XU, Adjunct Professor of Entrepreneurship

Undergraduate Business Administration

Oliver Hahl, Associate Dean, Undergraduate Programs; Associate Professor of Organization Theory, Strategy and Entrepreneurship

Jennifer Wegner, Assistant Dean, Undergraduate Programs

Location: Tepper Quad, Suite 2400

Email: uba@andrew.cmu.edu

Advising Appointment Online Scheduler: https://meetme.so/TepperAdvising

The Business Administration Major in the Tepper School of Business is for students interested in a broad undergraduate education based on management science, quantitative reasoning, leadership development, and communications skills. The curriculum is rigorous and flexible to accommodate student interests, academic, and career goals.

Students who complete the B.S. in Business Administration will be able to: i) Demonstrate a depth of knowledge in business functional areas; ii) Solve business problems using analytic methods; iii) Use diverse and broad intellectual frameworks to solve problems; iv) Develop judgment and the ability to work in diverse environments; and v) Communicate effectively and persuasively.

The curriculum includes a central core of courses in the functional areas of business, economics, mathematics, communications, and university courses in liberal arts and sciences. Students complete an in-depth study in one functional business concentration and additional business electives. Students also complete a minor from outside the Tepper School of Business to enhance their business education. The minor promotes students' intellectual confidence and leads to the broad knowledge that can last a lifetime. The curriculum structure helps Tepper graduates become leaders in complex global business, technical, and political environments.

Beyond the major in Business Administration, the Tepper School offers minors and additional majors to students in other programs of the university.

B.S. Degree in Business Administration

To receive the B.S. degree in Business Administration, students must complete at least 364 units, consisting of the requirements for the Business Foundations, Business Core, Concentration, Business Electives, University Core, and a Minor.

Business Foundations

Mathematics		Units
21-120	Differential and Integral Calculus	10
or 21-111 & 21-112	Calculus I and Calculus II	
21-256	Multivariate Analysis	9
or 21-259	Calculus in Three Dimensions	
70-257	Optimization for Business	9
or 21-257	Models and Methods for Optimization	
or 21-292	Operations Research I	
Economics		
73-102	Principles of Microeconomics	9
or 73-104	Principles of Microeconomics Accelerated	
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
or 73-240	Intermediate Macroeconomics	
Statistics		
70-207	Probability and Statistics for Business Applications	9
or 36-200	Reasoning with Data	
70-208	Regression Analysis	9
or 36-202	Methods for Statistics & Data Science	

Business Core

		Units
70-106	Business Science	9
70-110	Business Computing	9
70-122	Introduction to Accounting	9
70-311	Organizational Behavior	9
70-332	Business, Society and Ethics	9
70-340	Business Communications	9
70-345	Business Presentations	9
70-371	Operations Management	9
70-381	Marketing I	9
70-391	Finance	9
70-104	Business Leadership Endeavor I	3
70-204	Business Leadership Endeavor II	3
70-304	Business Leadership Endeavor III	3
70-401	Management Game	12
or 70-447	Client Consulting Project: Strategic Management of the Enterprise	

Concentration

Students must complete one concentration that allows them to gain knowledge and expertise in a particular area of business practice. For students electing to complete an additional major, the concentration requirement is waived (as is the minor requirement) and students must complete three business elective courses as part of the waived concentration requirement. Concentration courses cannot double-count with any other degree requirement including the minor requirement.

- Accounting
- Business Analytics and Technologies
- Entrepreneurship
- Finance
- Global Economics and Business
- Islamic Business Management
- Marketing Management
- Operations Management
- Product Management
- Strategic Management

Business Electives

Students must complete 18 units of Business Electives. A business elective course is any Business course (70-3xx) that is not being used to satisfy another degree requirement. This can include 21-270 Introduction to Mathematical Finance and upper-level Economics courses (73-3xx and above). Business Electives cannot double-count with any other degree requirement, including the minor.

Minor

In order to obtain the degree, students must complete a minor from another academic department. For students electing to complete an additional major or dual degree, the minor and concentration requirements are waived and the student must complete 9 additional units of business elective coursework.

university core

Students are required to complete Tepper School University Core, the general education coursework in the liberal arts and sciences.

CoRE @ Carnegie Mellon

All undergraduate students are required to take 99-101 (http://coursecatalog.web.cmu.edu/search/?P=99-101) CORE @ Carnegie Mellon to graduate (completed during the first year).

Business Concentrations

The business concentration allows students to gain knowledge and expertise in a particular area of practice. The concentration coursework prepares students with the knowledge and skills for their career pursuits and completing a concentration is part of the business degree requirements.

Business concentrations require at least 36 units beyond the Business Core. Courses taken to meet concentration requirements are not allowed to double count toward any other BA degree requirements, including the minor requirement. Business concentrations may require prerequisites from courses outside the concentration.

Accounting

Required:
70-424 Corporate Financial and Sustainability Reporting

Choose 3 remaining courses from:
70-422 Managerial Accounting
70-427 Modern Banks: Strategy and Regulation
70-428 Financial Statement Analysis
70-498 Business Language Analytics: Mining Financial Texts and Graphs

Business Analytics and Technologies

Required, choose 1 from:
70-374 Data Mining & Business Analytics
70-467 Machine Learning for Business Analytics

Choose 3 remaining courses from:
70-374 Data Mining & Business Analytics
70-387 Strategy for High-Tech Products and Services
70-455 Data Management Fundamentals
70-458 Advanced Data Management
70-460 Mathematical Models for Consulting
70-467 Machine Learning for Business Analytics
70-469 End to End Business Analytics
70-498 Business Language Analytics: Mining Financial Texts and Graphs
73-366 Designing the Digital Economy
73-374 Econometrics II

Entrepreneurship

Required:
70-415 Introduction to Entrepreneurship
70-416 New Venture Creation

Choose 2 remaining courses from:
70-395 Funding Entrepreneurial Ventures70-409 Innovation and Entrepreneurship in Emerging Markets
70-438 Commercialization and Innovation
70-443 Digital Marketing and Social Media Strategy
49-300 Integrated Product Conceptualization

70-509 (http://coursecatalog.web.cmu.edu/search/?P=70-509) Independent Study in Entrepreneurship (special permission required)

FINANCE

Required:
70-492 Investment Analysis
70-495 Corporate Finance

Choose 2 remaining courses from:
70-337 Business of Blockchain
70-353 Financial Regulation in the Digital Age 70-388 Islamic Finance
70-398 International Finance
70-484 Data Science for Finance
70-493 Valuation and Financial Modeling
70-497 Derivative Securities
70-498 Business Language Analytics: Mining Financial Texts and Graphs

Global Economics and Business

Required:
73-265 Economics and Data Science

Choose 1 course from:
73-347 Game Theory Applications for Economics and Business
73-421 Emerging Markets

Choose 2 remaining courses from:
70-398 International Finance
73-341 Managing through Incentives
73-354 Sports Economics
73-365 Firms, Market Structures, and Strategy
73-366 Designing the Digital Economy
73-427 Sustainability, Energy, and Environmental Economics

islamic BUSINESS management*

Required:
70-388 Islamic Finance
73-369 Islamic Economics

Choose 2 remaining courses from:

70-342	Managing Across Cultures	9
70-409	Innovation and Entrepreneurship in Emerging Markets	9
70-492	Investment Analysis	9
or 70-495	Corporate Finance	
73-421	Emerging Markets	9

**The Islamic Business Management concentration requires courses only available at CMU-Q.*

MARKETING MANAGEMENT

Required:
70-481 Marketing Research

Choose 3 remaining courses from:
70-385 Consumer Behavior
70-387 Strategy for High-Tech Products and Services
70-443 Digital Marketing and Social Media Strategy
70-482 Pricing Strategy
70-483 Advertising and Marketing Communications
70-485 Product and Brand Management

OPERATIONS MANAGEMENT

Required:
70-460 Mathematical Models for Consulting
70-471 Supply Chain Management

Choose 2 remaining courses from:
70-373 Sustainable Operations
70-422 Managerial Accounting
70-447 Client Consulting Project: Strategic Management of the Enterprise
70-462 Uncertainty and Risk Modeling
70-476 Service Operations Management
70-493 Valuation and Financial Modeling

PRODUCT MANAGEMENT

Required:
70-387 Strategy for High-Tech Products and Services
70-452 Introduction to Product Management

Choose 1 course from:*
05-391 Designing Human Centered Software
05-410 User-Centered Research and Evaluation

70-389 Design Thinking for Business: Creative Solutions for Complex Problems

**For business majors with an HCII minor or additional major the requirement is waived and students are required to take 2 courses from 70-385, 70-443, 70-481, 70-482.*

Choose 1 course from:
70-385 Consumer Behavior
70-443 Digital Marketing and Social Media Strategy
70-481 Marketing Research
70-482 Pricing Strategy

Strategic Management

Required:
70-437 Strategic Management and Innovation

Choose 3 remaining courses from:
70-387 Strategy for High-Tech Products and Services
70-341 Team Dynamics and Leadership

70-342 Managing Across Cultures

70-385 Consumer Behavior

70-424 Corporate Financial and Sustainability Reporting
70-432 Diversity, Equity, & Inclusion and Business Strategy

Additional Major in Business Administration

Students are eligible to apply for the Additional Major in Business Administration after completion of the Minor in Business Administration requirements plus 21-120 Differential and Integral Calculus and 70-207 Probability and Statistics for Business Applications (or equivalent course).

The following courses are required for the Additional Major:

Business Foundations

Mathematics		Units
21-120	Differential and Integral Calculus	10
or 21-111 & 21-112	Calculus I and Calculus II	
21-256	Multivariate Analysis	9
or 21-254	Linear Algebra and Vector Calculus for Engineers	
or 21-259	Calculus in Three Dimensions	
70-257	Optimization for Business	9
or 21-257	Models and Methods for Optimization	
or 21-292	Operations Research I	
Economics		
73-102	Principles of Microeconomics	9
or 73-104	Principles of Microeconomics Accelerated	
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
or 73-240	Intermediate Macroeconomics	
Statistics		
70-207	Probability and Statistics for Business Applications	9
or 36-200	Reasoning with Data	
70-208	Regression Analysis	9
or 36-202	Methods for Statistics & Data Science	

Business Core

70-110	Business Computing	9
70-122	Introduction to Accounting	9
70-311	Organizational Behavior	9
70-332	Business, Society and Ethics	9
70-340	Business Communications	9
70-345	Business Presentations	9
70-371	Operations Management	9
70-381	Marketing I	9
70-391	Finance	9
70-401	Management Game	12

Business Electives

Students must also complete a minimum of 18 units with a maximum of 21 units in Business courses (70-3xx). The electives cannot include the Business Leadership Endeavor courses (70-104 Business Leadership Endeavor I, 70-204 Business Leadership Endeavor II, 70-304 Business Leadership Endeavor III) and Independent Study/Internship courses.

Double-Counting Restriction

Students pursuing the additional major may double-count two courses with any other major or minor requirements and are allowed unlimited double-counts for the business foundation courses. There are no double counting restrictions between the additional major and a student's home college general education requirements.

Minors

The Tepper School offers several minor options for students interested in studying business: Business Administration, Business Analytics and Optimization, Financial Management, Operations and Supply Chain Management, and Product Management.

The minor in Innovation and Entrepreneurship is offered by the Tepper School through the Integrated Design, Arts, and Technology (IDeATe) network. Students must follow IDeATe policies and procedures for this minor.

Application:

Students are eligible to apply for a minor upon completion of two required courses for the minor wherein they earn a 2.0 QPA or higher in said courses.

Double-Counting:

While there are no double counting restrictions between the minor and the student's home college general education requirements, only one minor course may double-count with any other major or minor requirements. The Minor in Operations and Supply Chain Management allows an additional double-count for a total of 2 courses that may double-count with any other major or minor requirements.

Minor in Business Administration

Required:

70-100	Global Business [1]	9
70-122	Introduction to Accounting	9
73-102	Principles of Microeconomics [2]	9
or 73-104	Principles of Microeconomics Accelerated	

[1] 70-100 Global Business is intended for first-year and sophomore students only. Juniors and seniors who did not complete 70-100 and pursue the business minor replace the course with a constrained elective. 70-106 Business Science can substitute for 70-100 only if 70-106 has already been completed by a former primary business major.
[2] If a student successfully passes the 73-102 waiver, this requirement is waived and the student must take an additional 9 units of either constrained or business electives as defined by the minor.

Constrained Elective (*choose one*):

70-311	Organizational Behavior	9
70-371	Operations Management	9
70-381	Marketing I	9
70-391	Finance	9

Business Electives: 18 units of 70-3xx courses.

- The electives cannot include: the Business Leadership Endeavor courses (70-104 Business Leadership Endeavor I, 70-204 Business Leadership Endeavor II, 70-304 Business Leadership Endeavor III), 70-207 Probability and Statistics for Business Applications, 70-208 Regression Analysis, and Independent Study/Internship courses.

Note: Students with a primary major in Information Systems using the Business Administration minor to complete the Information Systems concentration have restricted course options by the Information Systems major and should consult with their primary major advisor.

Minor in Business Analytics & Optimization

Students working toward the minor must take a Multivariate Calculus prerequisite course: 21-256 Multivariate Analysis or 21-259 Calculus in Three Dimensions or 21-254 Linear Algebra and Vector Calculus for Engineers.

Modeling Uncertainty (*choose one*):

70-207	Probability and Statistics for Business Applications	9
36-200	Reasoning with Data	9
36-220	Engineering Statistics and Quality Control	9
36-225	Introduction to Probability Theory	9

Business Analytics and Optimization Core (*required*):

70-467	Machine Learning for Business Analytics	9
or 70-374	Data Mining & Business Analytics	
or 15-388	Practical Data Science	
70-257	Optimization for Business	9
or 21-257	Models and Methods for Optimization	
or 21-292	Operations Research I	
70-469	End to End Business Analytics	9

Business Foundations Elective (*choose one*):

70-122	Introduction to Accounting	9
70-311	Organizational Behavior	9
70-371	Operations Management	9
70-381	Marketing I	9
70-391	Finance	9
73-102	Principles of Microeconomics [1]	9
or 73-104	Principles of Microeconomics Accelerated	

[1]Students may not use the 73-102 prerequisite waiver to satisfy this requirement.

Technical Elective (*choose one*):

70-208	Regression Analysis	9
70-374	Data Mining & Business Analytics	9
70-455	Data Management Fundamentals	9
70-458	Advanced Data Management	9
70-460	Mathematical Models for Consulting	9
70-462	Uncertainty and Risk Modeling	9
70-467	Machine Learning for Business Analytics	9
73-374	Econometrics II	9
15-388	Practical Data Science	9

Minor in Financial Management

Required:

70-391	Finance	9
70-493	Valuation and Financial Modeling	9
70-207	Probability and Statistics for Business Applications	9
or 36-200	Reasoning with Data	
or 36-220	Engineering Statistics and Quality Control	
or 36-218	Probability Theory for Computer Scientists	
or 36-225	Introduction to Probability Theory	

Elective Courses (*choose three*):

70-398	International Finance	9
70-428	Financial Statement Analysis	9
70-492	Investment Analysis	9
70-495	Corporate Finance	9
73-103	Principles of Macroeconomics	9
73-337	Business of Blockchain	9
21-270	Introduction to Mathematical Finance	9

Minor in Innovation & Entrepreneurship (IDeATe)

The minor in *Innovation & Entrepreneurship* is offered by the Tepper School of Business (https://www.cmu.edu/tepper/) as part of the Integrative Design, Arts, and Technology (http://coursecatalog.web.cmu.edu/schools-colleges/tepper/undergraduatebusinessadministrationprogram/ideate.cmu.edu) network. *Innovation & Entrepreneurship* is for thinkers, dreamers, problem solvers, and realists. Students quickly learn the myth of the lone creative genius is just that, a myth, and the most transformative ideas and viable businesses come from creativity and repeatable innovation processes, business strategies and models, focused work, and a commitment to tackling real-world problems to bring value to people and the market. Through multidisciplinary coursework and a diverse cadre of faculty experts in business, technology, engineering, and design you will learn how to research, ideate, visualize, and strategize taking an idea or venture forward from multiple perspectives and collaborations. You can expect to expand as a critical thinker while adding hard and soft skills in your toolkit through hands-on learning experiences.

Specifically, you will take courses that emphasize:

- Experiential learning by doing through real-world problems, scenarios, case studies, etc.
- Critical thinking skills to understand problems, analyze strategies, determine approaches
- Multidisciplinary teamwork and collaboration
- Innovation processes, business models, strategies, and approaches
- 2D and 3D prototyping and visualizing of concepts and solutions

The IDeATe undergraduate curriculum consists of ten areas, all of which can also be taken as minors. The themes of these areas integrate knowledge in technology and arts: Game Design, Animation & Special Effects, Media Design, Design for Learning, Sonic Arts, Innovation and Entrepreneurship, Intelligent Environments, Physical Computing, Soft Technologies, and Immersive Technologies in Arts & Culture. *For more information about IDeATe, please see the* Undergraduate Options *(p.) section of the Catalog.*

Innovation & Entrepreneurship Minor Requirements

Innovation **Entrepreneurial Mindset Course**

		Units
70-246	Innovation & Entrepreneurial Mindset	6

One Portal Course

For students without prior design or product design experience, one of the following:		Units
15-294	Special Topic: Rapid Prototyping Technologies	5
15-394	Intermediate Rapid Prototyping	5
51-236	Information Design	9
62-478	IDeATe: digiTOOL	9

For students without prior programming or computer science experience:		Units
15-104	Introduction to Computing for Creative Practice	10

One Entrepreneurship Course

		Units
70-415	Introduction to Entrepreneurship	9

One Venture Creation Course

		Units
70-395	Funding Entrepreneurial Ventures	9
70-416	New Venture Creation	9

One Innovation Process Course

		Units
70-438	Commercialization and Innovation	9

One Product Development Course

		Units
49-300	Integrated Product Conceptualization	12

Practice/Experience

Multiple possibilities, including:

- 70-416 New Venture Creation (if you did not take it as your Venture Creation option)
- The Swartz Center for Innovation and Entrepreneurship Innovation Scholars Program (http://www.cmu.edu/swartz-center-for-entrepreneurship/education-and-resources/experiential-learning/innovation-scholars/)
- The Swartz Center for Innovation and Entrepreneurship Project Olympus Probe (http://www.cmu.edu/swartz-center-for-entrepreneurship/education-and-resources/project-olympus/probes/student-probe-projects.html) - Working on your own startup (12 weeks full-time in summer or throughout one full academic year);
- Students may also, with prior approval of Dave Mawhinney, fulfill this requirement through an internship with a qualifying startup or product design firm (12 weeks, full-time). If interested in this option, students should contact Dave Mawhinney (http://www.cmu.edu/swartz-center-for-entrepreneurship/about/staff.html) during their internship search.

Double-Counting

No more than two minor courses may double-count toward a student's major core requirements or an additional minor's core requirements.

Minor in Operations & Supply Chain Management

Required:

73-102	Principles of Microeconomics [1]	9
or 73-104	Principles of Microeconomics Accelerated	
70-371	Operations Management	9
70-257	Optimization for Business	9
or 21-257	Models and Methods for Optimization	
or 21-292	Operations Research I	
70-471	Supply Chain Management	9
70-460	Mathematical Models for Consulting	9
or 70-477	Real Options: Creating Value Beyond NPV	

[1]If a student successfully passes the 73-102 waiver, this requirement is waived and the student must take an additional 9 units of business electives (70-3xx). The electives cannot include the Business Leadership Endeavor courses (70-104 Business Leadership Endeavor I, 70-204 Business Leadership Endeavor II, 70-304 Business Leadership Endeavor III), 70-207 Probability and Statistics for Business Applications, 70-208 Regression Analysis and Independent Study/Internship courses.

Engineering Project Management (*choose one*):

06-421	Chemical Process Systems Design	12
12-411	Project Management for Engineering and Construction	9
18-540	Rapid Prototyping of Computer Systems	12
18-578	Mechatronic Design	12
19-451-19-452	EPP Projects I-II	12
24-370	Mechanical Design: Methods and Applications	12
42-402	BME Design Project	9
88-451-88-452	Policy Analysis Senior Project-Policy Analysis Senior Project	12

Minor in Product Management

Required:

70-381	Marketing I	9
70-387	Strategy for High-Tech Products and Services	9
70-452	Introduction to Product Management	9
73-102	Principles of Microeconomics *	9
or 73-104	Principles of Microeconomics Accelerated	

*** If a student successfully passes the 73-102 waiver, this requirement is waived and the student must take an additional 9 units of minor coursework.**

Course in Design Thinking (*choose one*):

70-389	Design Thinking for Business: Creative Solutions for Complex Problems	9
05-391	Designing Human Centered Software	12
05-410	User-Centered Research and Evaluation	12

Marketing Course (*choose one*):

70-385	Consumer Behavior	9
70-481	Marketing Research	9
70-482	Pricing Strategy	9
70-483	Advertising and Marketing Communications	9

Undergraduate Business Administration Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

70-100 Global Business

Fall and Spring: 9 units
The course is for non-Tepper BA students and provides a comprehensive overview of business, including how enterprises determine goals, strategies and operational tactics in competitive markets and the increasingly global environment. It covers different types of businesses - entrepreneurial and corporate, industries, markets, and economies. Students learn about the role of business in society, the various functional areas that make business work, and how companies develop plans and processes to achieve their goals for customers, shareholders, and employees. The course has special emphasis on providing a broad overview of business to augment students' major area of study for their professional development. Declared Tepper BA students are not eligible to enroll.This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.

70-104 Business Leadership Endeavor I

Fall and Spring: 3 units
Business Leadership Endeavor (BLE) is a required 3-mini course sequence (70-104,70-204,70-304) offered to undergraduate business students only. BLE 70-104 is the first mini of the BLE course sequence. Each previous mini will serve as a pre-requisite for the next in sequence. BLE introduces students to their leadership journey via four development frameworks: student development, personal development, professional development, and community development. BLE 70-104 will introduce students to the fundamental building blocks required for their development. Students will learn to develop and improve habits, sharpen personal and professional development skills, and develop meaningful networks. This course uses course material that requires students to pay an additional course fee.
This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.

70-106 Business Science

Fall: 9 units
This course is only available for Business Majors. The focus on the class is on the three core "lenses" used to study and advance the science and practice of business. We will study: the mathematics of optimization, economics, and the behavior in and of organizations. These are the foundations of the disciplines of finance, accounting, marketing, ..., that follow in the curriculum. Over the course of the semester, we will tackle complex multifaceted business problems. Think of examples like, bike-share and the "share-economy," international trade and supply chain, AI and the impact on work. For each case, we will work to apply the three lenses. A pillar for the semester is that business problems are not siloed in narrow disciplines, we must draw resources from disciplines across the entire university. The second pillar of our class is solving all problems - across all of society - requires your understanding of business science.
This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.

70-110 Business Computing

Intermittent: 9 units
Students will learn how individuals and organizations use computing technologies to support and improve their businesses. At an individual level, students will build their skills with Microsoft Excel and other personal productivity tools. At an organizational level, the class looks at ways in which businesses of all sizes and types leverage computing technologies to run their businesses more efficiently, make better business decisions, and create new business opportunities. This course is reserved for first-year Business students; others may enroll by special permission from the UBA office only.

70-122 Introduction to Accounting

Fall and Spring: 9 units
This course provides the knowledge and skills necessary for the student to understand financial statements and financial records and to make use of the information for management and investment decisions. Topics include: an overview of financial statements and business decisions; the balance sheet, the income statement, and the cash flow statement; sales revenue, receivables, and cash; cost of goods sold and inventory; long-lived assets and depreciation, and amortization; current and long-term liabilities; owners' equity; investments in other corporations; an introduction to financial statement analysis and international issues dealing with financial statements. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.

70-204 Business Leadership Endeavor II

Fall and Spring: 3 units
Business Leadership Endeavor (BLE) is a required 3-mini course sequence offered to undergraduate business students only. BLE 70-204 is the second mini of the BLE course sequence. Each previous mini will serve as a pre-requisite for the next in sequence. BLE introduces students to their leadership journey via four development frameworks: student development, personal development, professional development, and community development. BLE 70-204 will help students assemble their fundamental building blocks in a way that supports their continued development.
The course will continue to emphasize the importance of strong habits, meaningful networks, and ongoing skill development. Students will begin to connect this development with personal and professional goals. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 70-104 or 70-105

70-207 Probability and Statistics for Business Applications

Fall and Spring: 9 units
Elementary ideas in probability, statistics, and data analysis are presented in the context of their importance to modern business management.
This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.

Course Website: http://tepper.cmu.edu/prospective-students/course-page/70207/probability-and-statistics-for-business (http://tepper.cmu.edu/prospective-students/course-page/70207/probability-and-statistics-for-business/)

70-208 Regression Analysis

Fall and Spring: 9 units
This class focuses on the statistical analysis of the relationship between two or more random variables. In particular, we examine the estimation of the conditional mean of the dependent variable as a function of independent variables using linear regression. We draw on statistical theory to determine the precision of our estimates and to conduct inference about the population, and we examine a number of applications to business, finance, and economics throughout the course. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 36-201 or 36-218 or 36-247 or 70-207 or 36-200 or 36-207 or 36-220

Course Website: http://tepper.cmu.edu/prospective-students/course-page/70208/regression-analysis (http://tepper.cmu.edu/prospective-students/course-page/70208/regression-analysis/)

70-213 The American Railroad: Decline and Renaissance in the Age of Deregulations

Intermittent: 6 units
Railroads in the USA are often considered as a subject for nostalgia or public sector failure, an image largely based on passenger service. However, the USA's private sector freight rail industry is considered a model for the world as the result of its renaissance following deregulation in 1980. This is a "stealth" industry whose history and economics are both intertwined and complex. Students will gain a basic understanding of the industry's history and economics and its role in the national transportation network, with special attention to the past half-century. In addition, students will participate in small group research projects in particular areas of special interest - for example, economic history, industry and safety culture, network economics, utility regulation or transportation policy.

70-244 Contract Law and Strategy for Entrepreneurs

Intermittent: 6 units
This course explores the legal principles underlying contracts and their strategic implications in business settings. Through case studies, discussions, and practical exercises, students will develop a deep understanding of contract law and its application to real-world business scenarios. Emphasis will be placed on negotiating, drafting, and managing contracts, to further master key legal concepts and their strategic application in related areas of intellectual property, corporate governance, transactions, and risk management. Examining the importance of contracts and other legal issues facing entrepreneurs is critical to anticipating challenges that may arise as a company grows.

70-246 Innovation & Entrepreneurial Mindset

Intermittent: 6 units
This course is designed to introduce students to the theory and frameworks used to develop and implement innovative solutions to societal and entrepreneurial problems. The curriculum incorporates the latest on innovative behavioral traits and frameworks with a highly experiential format to expose undergraduate students to out of the box thinking. For example, the instructor would use the lecture section of the class to explain the behavioral techniques that lead to innovative solutions (based on the Innovator's DNA by Clayton Christensen). Teams of 3-6 students each would then examine a problem and be asked to generate 3 potential solutions and a proposed solution, using the techniques presented. Volunteers from the local Carnegie Mellon and entrepreneurial community will serve as mentors and judges, thereby providing a real world learning and networking experience. Ultimately, the best solution will be selected, using a shark tank format. While the selection of a winning solution will be fun for the class, the students will be graded on their having demonstrated the theory and amp; techniques presented in class. Each week will address a new and important topic related to the innovative and amp; entrepreneurial mindset. Weekly format will include one day of lecture and one day of application of the theory introduced in a fun and competitive format. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.

70-257 Optimization for Business

Fall and Spring: 9 units
This course provides a mathematical foundation for the application of optimization techniques to business problems, as well as the practical implementation of these methods. Mathematical optimization techniques have been applied for decades in the context of logistics, supply chain management, and strategic planning, with great success. In this course, the most important methods and techniques underlying mathematical optimization are studied. These include linear programming, integer programming, and nonlinear programming as basic mathematical methodologies. Based on these, we also consider methodologies for particular problem classes such as network models and traveling salesman problems. During the course we will emphasize mathematical modeling, that is, creating a mathematical description that reflects a given practical problem described in words. Motivated by these mathematical models, we then discuss the necessary mathematical techniques for finding optimal solutions. Lastly, we consider the solution of these problems using optimization software, i.e., we represent the mathematical models in Excel and use Excel Solver to compute an optimal solution. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 21-259 or 21-256 or 21-254

70-258 Developing Blockchain Use Case

All Semesters: 6 units
Blockchains, or distributed ledger and consensus technologies, hold tremendous promise for improving markets and organically handling private, secure data. As CMU develops its own blockchain and token and #8212;-CMU Coin and #8212;-a central concern is to determine the set of applications that such technology would be most useful for. This course is designed for students to propose and, potentially, develop applications or use cases for a campus blockchain. http://tinyurl.com/cmucoincourse (http://tinyurl.com/cmucoincourse/) The course begins with a brief introduction to blockchain using Bitcoin as an example of a blockchain protocol. We will examine the market failure Bitcoin was intended to resolve as well as the role of cryptography and distributed systems in enabling this new technology to create societal value. The course will go on to discuss the boundaries of the role of cryptography in blockchain. Next, we will use these tools to evaluate existing, real-world blockchain use cases with an eye towards developing our own applications of these emerging technologies. Along the way, we will learn practical development skills in distributed ledger technologies to understand blockchain programming and application development. Finally, students will propose their own blockchain use cases for CMU's own proprietary blockchain. No formal prerequisites, but familiarity with programming is highly recommended. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.

70-304 Business Leadership Endeavor III

Fall and Spring: 3 units
Business Leadership Endeavor (BLE) is a required 3-mini course sequence offered to undergraduate business students. BLE 70-305 is the third mini of the BLE course sequence. BLE introduces students to their leadership journey via four development frameworks: student development, personal development, professional development, and community development. BLE 70-305 will continue to build strong personal and professional skills as students get closer to their professional endeavors. Students will be applying learned skills in and out of the classroom and will begin to see the how the assembled skills are beneficial to themselves and others. This course will emphasize the importance of continued broad growth and lifelong learning. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 70-204 or 70-205

70-311 Organizational Behavior

Fall and Spring: 9 units
This course examines the factors which influence individual, group and firm behavior in the context of the workplace. Topics covered include perception, group behavior, decision making, motivation, leadership and organizational design and change. This course uses course material that requires students to pay an additional course fee. The course material is secured by the Tepper School because it is otherwise unavailable and directly provided to each student. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 76-102 or 76-101 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108) or 76-245 or 76-331 or 76-347 or 76-327 or 76-102

70-318 Managing Effective Work Teams

Intermittent: 9 units
Over the past decade, managers have greatly expanded their use of teams to accomplish a wide variety of organizational objectives. Teams have emerged as a favorite work arrangement for such ongoing activities as developing new products, providing professional services, and starting new businesses. Temporary groups are frequently assembled for a multitude of purposes, such as making difficult decisions, solving cross-functional problems, generating ideas, or performing unique tasks. Indeed, groups and teams can be found at every level of the organization, from production crews on the shop floor to top management teams in the executive suite. Moreover, advances in communication technology have created the potential for people who are dispersed across the globe to collaborate virtually, creating many new opportunities and challenges for leaders of such teams. Teams are not a panacea, however. Even as they become a way of life in many organizations, widespread myths and misconceptions about teams often stand in the way of effective teamwork. At their worst, teams sometimes create more problems than they solve. The core content of the course is a series of team and group exercises, case analyses, and readings. The exercises are framed and analyzed in terms of readings, lecture, and in-depth class discussions. Much of the learning that occurs in the course will involve exercises, simulations, and cases that draw on students' current experiences in the class as well as their previous experiences in teams and organizations outside of this class.
Prerequisite: 70-311

70-321 Negotiation and Conflict Resolution

Intermittent: 9 units
This course will complement the technical and diagnostic skills you have learned in other courses. A basic premise of the course is that, while you will need analytical skills to discover optimal solutions to problems, you will also need a broad array of negotiation skills to implement these solutions and make sure that they are truly effective. Your long-term effectiveness - both in your professional and personal life - is likely to depend on your negotiating abilities. This course will give you the opportunity to develop these skills experientially and to understand the analytical frameworks that underlie negotiations. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 76-102 or 76-101 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

70-324 Emotions and Decision Making Within and Outside of Organizations

Intermittent: 9 units
In this seminar-style course, we will examine the role of emotions within and outside of organizations. Topics related to the course are likely to include theories of emotion, positive and negative emotions, emotions and decision making, emotion in teams, emotions in performance, justice violations, workplace attitudes, and revenge. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.

70-332 Business, Society and Ethics

Fall and Spring: 9 units
What sorts of ethical obligations do businesses have towards their customers, employees, and the public? This course will explore ethical challenges faced by modern corporations, and frameworks which can be used to develop responsible corporate policy. The course is divided into four main units: (1) autonomy and consent, (2) the scope and locus of corporate responsibility, (3) fair treatment and outcomes, (4) the limits of labor and commodification. This course may use copyrighted material. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 76-102 or 76-101 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

70-333 Communication Design for Business

Intermittent: 9 units
Communication design is the practice of conveying information visually through graphic elements such as typography, images, and layout. This course explores foundational principles of communication design essential for effective business communication. Through hands-on projects and industry-standard software like Figma, students learn to create visually impactful materials for various business contexts. Topics include understanding the psychology and use of color, studying fonts and their typographic arrangement, curating visual elements for balance and impact, utilizing negative space, and using icons, symbols, and visual storytelling for effective communication. Students will develop a strong visual literacy and personal identity, enabling them to convey complex ideas and enhance understanding in business communications, giving them a competitive edge in the professional world.

70-334 Ethics of Emerging Technologies

Intermittent: 9 units
New technologies transform the ways that companies deliver value to consumers, but they also raise important ethical challenges. We will examine these challenges with the goal of developing strong normative arguments for corporate policies. Topics covered include: online data collection, media, and marketing; metaverse and virtual reality platforms; autonomous objects; genetic screening and engineering; neural screening and engineering; narrow and general artificial intelligence. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 76-101 or 76-102 or 70-332 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

70-337 Business of Blockchain

Intermittent: 9 units
Economics and business strategy is fundamental for the design and development of blockchain use cases. This course will introduce students to foundational economic concepts to help them understand the role cryptocurrencies play in securing blockchains, how different ``tokenomics'' models impact cryptocurrency prices, the different means to create liquidity or resolve illiquidity in decentralized finance (DeFi) applications such as stablecoins, collateralized-lending, yield farming, or automated market making, the roles of Central Bank Digital Currencies, as well as models to evaluate the value-added of blockchain-based versus traditional business propositions. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: (73-102 Min. grade C or 73-104 Min. grade C) and 73-103 Min. grade C

70-339 FinTech

Intermittent: 9 units
The financial services industry is a leader in the use of information technology. Firms in banking, securities, investments, insurance and financial marketplaces are among the most information intensive and innovative users of technology. The course will examine the role and potential of technology in this industry. The course begins with a description of the financial markets, specifically equity, foreign exchange, and derivatives, and the systems that enable them. It considers exchanges, ECNs, ATS's Order Management Systems, Straight through Processing, Fix Protocol, and post trading clearance and settlement. It covers the design, evaluation and execution of popular trading strategies that are used by professionals in the various markets. There is increasing interest, in particular, on systematic trading strategies and execution systems because of their scalability and transparency. The course covers both Algorithmic and High Frequency Trading and analyzes issues regarding latency, scalability, and reliability. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisite: 70-391

70-340 Business Communications

Fall and Spring: 9 units
Business Communications develops and sharpens your written, oral, and interpersonal communication, introducing you to common forms of professional writing and speaking in specific business situations. The course explores crucial rhetorical issues that impact your ability to communicate and achieve your objectives as a business leader. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 76-102 or 76-101 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

70-341 Team Dynamics and Leadership

Intermittent: 9 units
Organizations have greatly expanded their use of teams to accomplish a wide variety of objectives. Teams develop new products, provide professional services, and start new businesses. Temporary teams are frequently assembled to make difficult decisions, solve cross-functional problems, and generate new ideas. Advances in communication technology allow people dispersed across the globe to collaborate virtually, creating many new opportunities and challenges for leaders of such teams. This course will provide you the knowledge and skills to communicate in teams and to lead them effectively. It will help you better communicate in and lead teams and organizations. You will learn both effective leadership practices as well as how to avoid common leadership mistakes. Our readings reflect both the scientific and practice literatures and class exercises, cases, and projects provide the opportunity to apply what you learn. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 36-201 or 36-220 or 36-247 or 36-200 or 36-225 or 36-207 or 36-217 or 70-207

Course Website: http://tepper.cmu.edu/prospective-students/course-page/70341/organizational-communication (http://tepper.cmu.edu/prospective-students/course-page/70341/organizational-communication/)

70-342 Managing Across Cultures

Intermittent: 9 units
This course is designed for students who expect to do business in other countries or work with people from other cultures. It provides an intellectual framework for understanding other cultures (and eventually one's own), as well as detailed studies of particular countries. It discusses how culture defines organizations, contracts, personal relationships, attitudes toward authority, time and space, ethics, wealth, and subcultures, and how these affect business. Student teams study a culture of their choice and make presentations, based on interviews and literature research. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 76-101 or 76-102 or (76-108 and 76-107) or (76-107 and 76-106) or (76-106 and 76-108)

70-344 Internet Ethics

Intermittent: 3 units
The use and abuse of social media and other online platforms has become a major global issue. This course provides a conceptual framework for analyzing some of the ethical controversies these practices raise. Controversial practices include collection and selling of personal data, promotion of rumor and misinformation, cyberbullying, manipulation of social media newsfeeds, and electronic surveillance, as well as efforts by Internet platforms to curtail these activities. Student teams will analyze and ethically evaluate the Internet activities of a platform or company of their choice and present their findings to the class.

70-345 Business Presentations

Fall and Spring: 9 units
In this course, students prepare, present, discuss, and critique different oral presentations currently practiced in business. Topics include developing your presence in a professional setting; projecting credibility, professionalism, and authority; and planning presentations to influence business audiences. Assignments and cases will cover informative and persuasive presentations, which will vary from term to term and may include talks such as product pitches, team-driven strategic plans, and state-of-the-company addresses. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 73-270 or 70-340

70-348 Cross-Cultural Business Communications

Intermittent: 9 units
This course considers cultural behaviors, assumptions, values, and conflicts surrounding business communication across cultures. It will begin with an evolving definition of "culture" and consider several cultural variables that may affect communicative success (i.e. collectivist/individualist cultures, high-/low-context languages, monochronic/polychronic cultures). Students will research and present findings on the characteristics of specific cultures. They will prepare business documents and presentations that build on the knowledge and skills acquired in 70-340, Business Communication, and reflect new sensitivities to the needs of specific cross-cultural audiences. This course is offered only at the Carnegie Mellon-Qatar campus.
Prerequisites: 76-270 or 70-340 or 15-221

70-350 Acting for Business

Intermittent: 9 units
Perception may or may not be Reality. But Perception is, in fact, what Influences people. This experiential communications course focuses on how you as a Leader can choose to more effectively express yourself and amp; influence others using practical, hands-on tools from Acting in professional, live Theatre. You will choose to effectively Influence your Listeners' perception of you through the use of: "Action"; Assertiveness, Confidence and amp; Expressiveness (ACE); the Visual, Aural and amp; Temporal Communication Tools; and the incorporation of The Seven Steps Of Effective Influence (or core competencies). This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.

70-352 Business Acting

Spring: 3 units
This is a one-week course that is offered only at CMU in Qatar. This course provides a uniquely broadening educational experience for business students through an exploration and amp; understanding of the process of Acting and amp; the unique performer/audience relationship. Using techniques of Acting, the course will concern itself with: a new self-awareness and amp; greater confidence in public communication; the expansion and amp; diversification of one's range of personal expression; methods to more effectively shape a public performance and amp; of empowering the student to put his/her best Self forward when in contact with an audience; and amp; a re-investment in passion.

70-353 Financial Regulation in the Digital Age

Intermittent: 9 units
The course will address the foundations of regulation (why regulate?) from various perspectives within the context of a market economy, highlighting the sources of market failure (such as externalities, adverse selection, and natural monopoly) and potential remedies (such as taxes and fees, disclosure, price regulation, guarantees). The conflicting goals among regulators (and why we have multiple regulators) and their impact on the meaning of regulation will be considered along with regulatory competition/arbitrage. Portions of the course will tackle relatively broad questions such as: Why regulate? What is the law of unintended consequences? What is the objective of a policy advocate? Are regulators and regulatory policies a systemic risk? Are our markets rigged? How can regulators enhance the predictability and credibility of their policies? How costly were government guarantees during the financial crisis? Should we bar insider trading? Should regulations be determined and motivated based upon cost-benefit analysis? How can we evaluate the success or failure of particular regulations and whether they have achieved their objectives? How does the Dodd-Frank Act promote financial stability? What basic aspects of the financial crisis did Dodd-Frank not address? (Lecture, 3 hours). Minimum grade standard of "C" applies only to economics courses. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: (21-112 or 21-120) and (21-269 or 21-256 or 21-268 or 21-259) and 73-230

70-354 Communication: Social Media in Action

Intermittent: 6 units
Building upon what you already learned in Business Communications, this course will amplify your ability to successfully work in teams to produce social media content, collaborate via online mediums, and build online communication skills through development of an effective online presence. You will create and deliver social media content for your chosen organizations in this online space. This is a differentiator for you; after this course, you will be able to go into an interview confidently and share your team experience helping the organization build a successful social media presence. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 70-340 or 73-270

70-364 Business Law

Intermittent: 6 units
This course covers the fundamental principles of law that govern business affairs in the United States, with some reference to the laws of other countries. The topics include constitutional sources of business law, administrative agencies, contract law, agency, employment, business forms (corporations, partnerships, limited partnerships, limited liability companies, agency arrangements, franchises), intellectual property and unfair competition, legal liability of professionals, international trade and antitrust.
Prerequisites: 70-340 or 76-102 or 76-101 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

70-365 International Trade and International Law

Intermittent: 9 units
The course discusses the international legal system and laws that affect international trade. It covers the Foreign Corrupt Practices Act, treaties and concessions, shipping and customs, appointment of foreign sales agents, resolution of trade disputes, international mergers and joint ventures, international competition law, UN sales convention, international trade organizations (IMF, WTO, World Bank, etc.), risk insurance, cultural factors, international E-Commerce and intellectual property.
Prerequisites: 73-100 or 73-102

70-366 Intellectual Property and E-Commerce

Intermittent: 6 units
The course is intended to instruct students on the creation of the Internet and the World Wide Web, including the creation of the Domain Naming System. The course will provide an understanding of how the Web operates (from its creation to the present), how the laws of various countries interact with the Web; how issues of privacy are addressed and the role of private parties and government in monitoring privacy. The course will examine how intellectual property is created and protected; who owns the property; and the role of ownership of the intellectual property interacts with antitrust laws. The course examines how contracts are formed and administered on the Web by entities created to minimize taxes and personal liability risks for the owners/shareholders of those entities. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 76-102 or 76-101 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

70-371 Operations Management

Fall and Spring: 9 units
This course is an introduction to production and operations management that covers both manufacturing and services. It deals with strategic issues (design of flexible supply), planning issues (capacity management), and operational issues (inventory management and information). The linkage between strategy and tactics will be emphasized. The students will learn concepts and tools that will help them to manage from the "boardroom" to the "toolroom." This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 36-220 or 36-247 or 36-225 or 36-207 or 36-200 or 36-201 or 70-207 or 36-218

70-373 Sustainable Operations

Intermittent: 9 units
This course explores and defines sustainability in general, and sustainable operations in particular. The course investigates how companies can evaluate and implement sustainability measures, and different motivations for firms to engage or invest in sustainable efforts. Sustainable operations is approached from the value chain perspective, by identifying opportunities for sustainable actions and policies at different phases in the product life cycle. These phases range from research and development to the point where products are discarded by the consumer, for potential reuse or recycling. Quantitative operations models and techniques will be used to analyze and evaluate the viability of these sustainable opportunities. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 70-106 or 70-100

70-374 Data Mining & Business Analytics

Intermittent: 9 units
Interest in big data analytics has skyrocketed recently. The recent explosion in large-scale high-resolution data enables managers to ask and answer questions regarding businesses and consumers at a whole new level. Managers are faced with data about businesses and consumers that are growing faster than they can be utilized. Data mining enables business to extract useful consumer behavior and preferences from seemingly tremendous and unorganized data, which then can be utilized for data-driven decision-making and competitive advantage. Applications can be found in e-commerce, sales, marketing, finance, operations, etc. In this hands-on introductory class, you will learn the basic concepts and techniques of data mining in addition to when and how they can be applied to improve many aspects of business and consumers' welfare. Throughout the course, we will use R, a powerful open-source statistical language and one of the main tools in data mining and business analytics, fast becoming a mainstream tool. With this tool, you will learn about variety of exploratory and predictive data analytics techniques such as Naïve Bayes classifier, nearest neighbor approaches, decision trees, clustering algorithms, etc. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 36-202 or 70-208 or 36-208 or 36-225

70-376 Energy Systems

Fall: 9 units
This course will provide students with an understanding of the systems and markets that provide energy to businesses and consumers. Students will be introduced to the sources and uses of energy, and how they have evolved and the possible paths over which they may evolve in the next decades. The course places an emphasis on electric energy, the single largest energy source in many industrial economies, but also covers natural gas, oil, and selected other primary energy sources. Students will learn the energy flows in the USA and the world, as well as the business-relevant characteristics of the engineered systems that provide the energy in various forms. Both traditional and emerging energy sources will be discussed, and students will understand the difference between an energy carrier and an energy source. We will also discuss some of the issues that arise without proper management of the physical risks of energy systems. Students will learn some of the history of electric power regulation and the inconsistent subsidy structures that have provided opportunities and challenges for energy companies and investors, including discussion of how emissions restrictions affect fuel, engineering, investment, and project finance choices. The history of electric power markets will be discussed, with an eye to examining the opportunities that market changes create for business.

70-381 Marketing I

Fall and Spring: 9 units
An introduction to the nature and fundamentals of marketing and consumer behavior. Topics include an analysis of the economic and psychological factors influencing buyer behavior, marketing research, market segmentation, and the development of marketing programs (new product, price, advertising and distribution decisions). This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 76-102 or 76-101 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

70-385 Consumer Behavior

Intermittent: 9 units
Marketing, in particular, begins and ends with the consumer from determining consumer needs to ensuring customer satisfaction. In this course, we will explore the most recent scientific research in marketing, psychology, and behavioral economics on judgment and decision-making. We will develop your ability to understand and influence what people want, how people decide what and when to buy, and whether people will be satisfied or dissatisfied with their decisions. These psychological insights are particularly useful for marketing strategy, brand positioning, and marketing communication decisions, but also yield insight into common biases in judgment and decision making, beyond marketing, to which you would otherwise fall prey. Why people are willing to drive across town to save $5 on a tank of gasoline, for example, when they would not drive a minute to save $5 on a refrigerator. We will discuss some of these applications in class. In addition, we will examine the methodology of market research (specific to consumer behavior) to build the tools you will need to interpret and base decisions on it. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisite: 70-381

70-386 Applied Behavioral Decision Making For Business

Intermittent: 6 units
This course is intended to give future managers, consultants, and policy makers an introduction to the insights and applications of behavioral decision making. Behavioral decision making is the interdisciplinary study of how people make decisions. It draws together research from psychology, economics, political science, and management, among other fields. Topics include heuristics and biases in inference and prediction, risk perceptions and attitudes, and the roles of group and emotional processes in decision making. In this course we will address applications of these findings from the various behavioral sciences to the study of business.This course is offered only at the Carnegie Mellon-Qatar campus.
Prerequisites: (36-201 or 70-207 or 36-200) and 73-100

70-387 Strategy for High-Tech Products and Services

Intermittent: 9 units
This course will focus on the strategies of technology-based products and services. We will examine how technology products/services differ from non-technology-based products and how the unique attributes of high-technology products/services influence the marketing strategies and tactics of those products. We will cover issues such pricing of technology products/services including versioning, bundling and dynamic pricing; the impact of network effects within product markets; competition in technology-focused product arenas; the design, launch and governance of platform markets. Examples of technology-intensive industries that we will discuss are computer hardware and software, media and entertainment, telecommunications, e-commerce, and the sharing economy. Students explore the unique economic circumstances facing firms in these industries and identify strategies that enable firms to succeed given these circumstances. This course is ideal for students who want to pursue a career as a product manager for a technology company. This course helps students understand the unique economic characteristics seen in today's technology-intensive markets and how they impact the strategic interactions among firms and consumers. In order for students to understand how firms strategically interact in technology-intensive industries this course will use a combination of simple but rigorous analytical models, emerging theories, and formal case studies.

70-388 Islamic Finance

Intermittent: 9 units
This course is designed to introduce students to the basics of Islamic Finance. The course will start with an analysis of the Shariah rules that define Islamic Finance. Students will then look at the main investment structures and map these against the traditional conventional banking products. The course wraps up with a critique of complex project finance structures through a Shariah compliance lens to identify the gaps between theory and practice.

70-389 Design Thinking for Business: Creative Solutions for Complex Problems

Intermittent: 9 units
In today's rapidly evolving world, businesses constantly seek innovative solutions to complex problems. Design Thinking has emerged as a powerful process to address these challenges by fostering creativity, empathy, experience, and collaboration. This course introduces the principles, methods, and tools of Design Thinking and explores an array of techniques and frameworksfrom problem framing and creative ideation to prototyping and user testing. We will adopt the UN Sustainable Development Goals to bring positive changes to people and the planet and shape a more prosperous future for all.

70-391 Finance

Fall and Spring: 9 units
Firms create value by making good investment decisions. Finance is the field of management science tasked with making this happen. It is a set of tools with which firms identify good investments and decide how to pay for them. Paying for them ultimately involves getting money from households. Therefore, finance also describes the investment decisions of households and the resulting allocation of the economy's resources across firms and time. This course is the introductory finance course in the undergraduate business program. The main topics covered in the course are Financial Markets, Net Present Value, The Objective of the Firm, Discounted Cash Flow, Portfolio Theory and the Cost of Capital, The Efficient Markets Hypothesis, The Capital Structure of the Firm, and Business Valuation. Time permitting, the course will also provide an introduction to option markets and derivative securities. Upon completing the course a student will be able to consider a large and complex business problem, make some assumptions, structure the firms' cash flows in a spreadsheet, calculate the value of different solutions to the problem, and make a decision. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: (73-102 or 73-100 or 73-104) and (36-207 or 36-218 or 70-207 or 36-217 or 36-201 or 36-200 or 36-225)

70-395 Funding Entrepreneurial Ventures

Intermittent: 9 units
So you want to do a startup and you know that you need funding. There are multiple ways to fund a new venture: bootstrapping, economic development, angels, venture capitalists. The question is what are these funders looking for in an early stage investment? What is important to them? How do they decide which companies to invest in and which not? This class looks at funding from the funder's point of view and provides the student with a framework of the investment process: investment criteria, sourcing, selection, due diligence, deal structure, valuation, post investment involvement. Real companies seeking funding are used for the final project in which students will be expected, as investment teams, to make investment decisions and convince their fellow investors (the class) to join them (or not). This is a highly interactive and project class. There will be multiple guest speakers. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.

70-396 Applied Business AI

Intermittent: 6 units
This mini-semester course explores into the prudent and responsible use of AI assistants in business. In particular, we will emphasize AI applications, benefits, limitations, ethical considerations, and future implications. The core focus is on employing AI assistants to expedite work without compromising quality (prudent use) while minimizing negative externalities (responsible use). Throughout the course, students will develop and implement a pipeline for prudent and responsible use tailored to specific fields.
Prerequisites: 70-391 or 70-122

70-398 International Finance

Intermittent: 9 units
International Finance is an elective course designed to give students the opportunity to analyze real-world problems in international capital markets. Topics covered include: exchange rate determination and quoting, international parity relations, foreign exchange hedging strategies using forwards and options, foreign exchange exposure management, international bond market, currency swap market, global equity market, international portfolio risk assessment and performance measurement. Students develop problem solving and communication skills with presentations and critical discussions of case studies.
Prerequisite: 70-391

70-401 Management Game

Fall and Spring: 12 units
This course is designed to integrate the managerial concepts and techniques studied earlier in the curriculum and to focus on elements of organizational structure and behavior. Student teams assume the role of top management of firms competing in an international economy simulated by the Carnegie Mellon University Management Game. Each team is responsible to a Board of Directors comprised of alumni of the MBA program and business masters students. Emphasis is placed on the development and implementation of sound organizational decision structures as well as the formulation of effective competitive strategies. The course is reserved for senior-year business majors and additional majors. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 70-122 and 70-391 and 70-381 and 70-371

70-409 Innovation and Entrepreneurship in Emerging Markets

Intermittent: 9 units
This course focuses on the role that innovation-driven entrepreneurship and market-creating innovation play in the development of economies in emerging markets. The course will explore the potential economic development opportunities brought forward by market-creation innovations in emerging markets and will seek to understand the unique challenges and opportunities of innovation which face entrepreneurs in emerging markets.

70-412 Advanced Business Communications: Power, Persuasion, and Problem-solving

All Semesters: 9 units
Challenges such as communicating leadership and expertise to a newly formed team, receiving unclear expectations, limited time to complete a complex problem, persuading a reluctant colleague, showcasing yourself in a crucial performance review all occur in business. This advanced course digs deeper into how leaders and successful professionals navigate the complex workplace of surprise, ambiguity, crisis, and diversity. You'll explore varied, often high-stakes workplace scenarios to build your persuasive ability, linguistic skill, communicative flexibility, agility, and confidence.
Prerequisites: (70-345 and 70-340) or 73-270

70-415 Introduction to Entrepreneurship

Fall and Spring: 9 units
This course is an introductory course designed to provide an overview of entrepreneurship, develop an entrepreneurial frame of mind and learn the fundamentals of lean startup development. Students, Sophomore year or higher, interested in founding or contributing to a start-up venture, regardless of areas of discipline (engineering, design, business, computer science, music, drama, and more), are welcome. Students can expect to gain a basic understanding of functional areas such as customer discovery, sales, business planning, risk management, venture funding, and more. This class also features "The Sprint: An Entrepreneurship Competition," which affords the students the opportunity to gain experience selling their choice of product in a real-world and competitive environment. The class is a discussion- and project-based class. Class sections feature either a combination of lectures, class discussions, and activities or applied workshops in small groups. Students will be learning a mental framework for evaluating and amp; developing any startup and then applying said framework and techniques to analyze and execute real-world business opportunities. Interdisciplinary teams will generate ideas and explore their potential as viable businesses. Numerous student teams have completed this class with real-world opportunities. Guest speakers, case studies, and exercises will also be integrated. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course. Students enrolled in the course will be required to pay the University the associated additional course materials fee for the third-party course material provided ($13 to $75)

70-416 New Venture Creation

Intermittent: 9 units
This course exposes students to the nuances of financing new ventures, getting them started legally and marketing their products or services. Students pull together all the ideas and information from different functional aspects of their projects into coherent and persuasive mini-business plans that serve as roadmaps for building their businesses; and useful instruments to find sufficient financing for the new ventures, so that they can convince the outside world that these opportunities are viable, with substantial potential for success. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 70-420 Min. grade C or 70-415 Min. grade C or 70-421 Min. grade C or 70-425 or 15-390 or 70-414 Min. grade C

70-422 Managerial Accounting

Intermittent: 9 units
The purpose of this course is to prepare students to make sensible business decisions using accounting information. An essential topic in the course is the measurement and allocation of costs to assist decision making in organizations. The course covers standard topics in cost accounting, such as cost behavior and relevant costs, and connect these to broader issues in microeconomics, decision theory, corporate finance, and operations management. Classes contain a mixture of conventional lectures, problem solving, business cases, and simulations. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 70-122 and (70-207 or 36-200 or 36-207 or 36-201)

70-423 Technology-Based Entrepreneurship

Spring: 9 units
This course is offered only at Carnegie Mellon's campus in Qatar. This course is designed as an introduction to entrepreneurship and basic business concepts for engineering and science students. There are no prerequisites. Students learn basic business concepts, business models, entrepreneurial thinking, idea generation, opportunity recognition, and the basics of accounting, marketing and strategy development. There is no final examination. Instead, students, working in teams, generate an original idea for a startup business and prepare a business plan and an investor presentation, which sets forth the basic strategies, business models and evaluates the opportunity afforded by their original idea. This course also is consistent with the broad mission of Carnegie Mellon University in Qatar's entrepreneurship program, which is described below. The broad mission of the entrepreneurship program at Carnegie Mellon University in Qatar is three-pronged: a.To encourage and develop entrepreneurial and innovative thinking in a business setting, whether or not it is a startup company; b.To obtain the basic skills to start a new venture; c.To stimulate self-evaluation for life direction.

70-424 Corporate Financial and Sustainability Reporting

Intermittent: 9 units
This course is designed to strengthen your ability to understand and use both financial and sustainability data reported by corporations. For the past five centuries, massive and rich financial data has been generated and intensively used to aid investment decisions in capital markets and business strategies by corporations. More recently, the realm of financial reporting has been significantly augmented along the new dimension of sustainability reporting due to the rapidly growing trend of sustainability-oriented investing and investors' demand for sustainability-related data. The course is aimed at anyone whose career might involve working with financial and sustainability data and should be especially useful for those interested in investing, banking, and consulting careers. Throughout the semester, we will discuss the regulatory and corporate environments that govern the generating process of financial and sustainability data and how understanding such data-generating process helps with drawing implications from the financial and sustainability data about corporate valuations, business strategies, etc. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisite: 70-122

Course Website: http://tepper.cmu.edu/prospective-students/course-page/70424/corporate-financial-reporting (http://tepper.cmu.edu/prospective-students/course-page/70424/corporate-financial-reporting/)

70-427 Modern Banks: Strategy and Regulation

Intermittent: 9 units
What is the main role that banks play in the economy? Are banks safe and trustworthy? What are the main business areas of a modern full service bank and how does it make profit in each area? What are the main risks that they face and how do they manage those risks? How can the public assess the risks a bank faces and measure its performance? Does the regulation governing banking address these risks effectively? The main goal of this course is to examine these and related questions by focusing on the analysis of banks' financial reports. Students will learn how accounting and disclosure rules for financial instruments and institutions convey detailed information that is useful to evaluate their risks and performance. Potential limitations of the current financial reporting requirements facing banks will also be discussed. The course covers crucial topics in modern banking strategy and regulation such as interest rate risk, provision on loan losses, fair value accounting for financial instruments, repos, securitization, capital requirements, and derivative and hedge accounting. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 70-122 and 70-391

70-428 Financial Statement Analysis

Intermittent: 9 units
This course is about fundamental analysis using financial statements. We develop and apply technologies for understanding and identifying firm activities that generate shareholder value and for developing valuation benchmarks. The ultimate goal of such analysis is to aid the security valuation and risk analysis exercises. This course is intended to help students establish a good foundation and introduce students the basics of equity and debt analysis techniques. Taking Finance (70-391) before this course is recommended, though not a formal prerequisite. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisite: 70-122

70-429 Accounting for Financial Institutions

Fall: 9 units
The banking sector is important because it drives the financial growth of an economy. This sector accepts deposits from the public and issues loans, and thus the banking sector expands in response to positive changes in retail, corporate and government business demand. Similarly, if a slowdown occurs this results in a reduction in demand for banking sector services. As a result, the important starting point for a financial analyst, who wants to assess current and future economic growth, are the financial statements of banks and the information they contain. To extract this information, however, requires being able to read and interpret the financial statements of a bank. These statements are very different from reading traditional corporate financial statements. As a result, the first objective of this course is to learn how to read financial statements generated from the banking sector including how to interpret and evaluate these statements. The banking sector in Qatar is unique because it has two important and separate subsectors and #8212;- Islamic and conventional banking. Each of these subsectors have a different banking business model which in turn generate differences in their financial statements. As a result a second important objective for this course is to learn how to read and evaluate the financial statements from each of these subsectors.
Prerequisite: 70-122

70-430 International Management

Intermittent: 9 units
This course uses the case method to examine the strategic and operational issues in management practice and decision-making that are important in operating a business that spans national borders. Topics include political and economic risk assessment, technology transfer, cultural analysis, negotiation, social responsibility, organization structure, supply chain management and trends in foreign direct investment and their impact on developing strategies for entering and becoming successful in international markets.

70-433 Leading Innovation

All Semesters: 3 units
Organizations (startups and mature businesses alike) live in an age of constant change (i.e., technology evolution/revolution, globalization, deregulation). Over the past decades, breakthroughs such as artificial intelligence, machine learning, rapid computing, nano- and biotechnology have significantly accelerated the rate of innovation. The internet and digital connectivity have transformed information dissemination and global collaboration. The development cycle for new products and services have shortened, consumer demands becoming more dynamic and volatile. Organizations must innovate faster to stay relevant as the future becoming furthermore intelligent and dynamics. Innovation is not merely about creating something entirely new. It can also involve incremental changes or adaptations that significantly improve existing products, processes, or services. It often requires creativity, critical thinking, problem-solving, and a willingness to challenge the status quo. People are the agents of innovation. Managers of an organization are responsible for diagnosing challenges, analyzing applications, formulating strategies, building innovative teams, leveraging innovation for competitive advantages and sustained success. It is therefore essential for managers to develop necessary leadership skills that will enable them to successfully manage innovation. These skills are manifested through a firm understanding of the dynamics of innovation process. Leading Innovation is an essential course for managers to develop the skills, knowledge, and strategic perspective required to foster innovation within their organizations, ensuring sustainable growth, competitiveness, and relevance in a rapidly changing business landscape.

70-437 Strategic Management and Innovation

Intermittent: 9 units
This course focuses on how organizations deliver value in changing business environments, using analytical techniques to evaluate business situations and develop strategies that improve organizational performance. By focusing on the organizational perspective, you will develop practical skills in evaluating and designing ways for firms to achieve key strategic outcomes like growth and innovation, which determine the firm's chances of success in dynamic environments. This course is particularly useful if you are interested in careers such as consulting, business development, investment banking, private equity, entrepreneurship, or simply want a better understanding of how their firm can develop a more innovative outlook. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisite: 70-311

70-438 Commercialization and Innovation

Intermittent: 9 units
The course is targeted at entrepreneurs and innovators who are interested in introducing innovations to the marketplace through start-up, emerging and established organizations. Class participants will learn how to evaluate, develop and implement opportunities for innovation, using an emergent or iterative approach (the lean methodology). Students will also learn a variety of methodologies to identify opportunities for innovation including how to identify unserved customers, identifying what jobs customers need to do, and how to incorporate innovations originating from end users, suppliers, materials manufacturers, and other entities outside the firm. Students will learn how to develop a Business Model, identify a Minimum Viable Product, and a Market Entry Point. The course is divided into two parts. In the first half students will be exposed to theories and strategies of innovation through readings and case studies. In the second half students will identify and develop their own product concept utilizing concepts developed in the first part of the course, and step-by-step develop their business model, organizational plan, strategic partners, marketing message, sales plan, and financing strategy. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: (73-102 or 73-104 or 73-100) and (70-421 or 70-420 or 15-390 or 70-415 or 70-414 or 70-425)

70-439 Applied Data Science for Business

Intermittent: 9 units
The objective of this project class is to expose students to cutting-edge data science tools applied to a real-world problem. This project course fulfills several academic goals, by applying business analytics and leadership to an actual industrial application. These include: Team management: Learn how to interact and engage with your team members, set goals, and manage the project. Leadership: The project contains different elements, such as coding, writing, and presenting, which allows students to take ownership and lead that part of the project. Analytics: The project contains several analytical components including data analysis and predictive modeling. Product Management: Learn how data and analytics can bring value to a new product.

70-440 Corporate Strategy

Intermittent: 9 units
This course is designed to provide the student with a general management perspective and an understanding of the total business enterprise. It builds upon previous course work in functional areas and provides insights and analytical tools which a general manager should have in order to plan and implement successful business strategy. The student will analyze complex business problems and formulate realistic strategic solutions. Emphasis is placed on the practical application of business theory by the student in their business career.

70-443 Digital Marketing and Social Media Strategy

Intermittent: 9 units
This course explores issues related to digital and social media marketing. This is a hands-on class where students utilize real world data. Specifically, we study the following topics: (a) Search Engine and Sponsored Search Optimization: how search engines, keyword auctions, retargeting, mobile marketing, social network marketing and search engine marketing work, and how to optimize pay per click advertisement efforts. (b) Econo-Mining: how firms are getting or can get useful information from user generated content using text mining and opinion mining capabilities to drive their product development, placement, and advertisement decisions. (c) Social Media/Viral Marketing: how to design a social media marketing campaign; the key ingredients that make such campaigns successful; how to run a campaign for a viral product; measuring the success of a social media campaign (d) Wisdom of the Crowds: how to design crowdsourcing contests; what and how to crowdsource; prediction markets and how to design them for success and the kinds of questions are best suited for prediction markets. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.

70-447 Client Consulting Project: Strategic Management of the Enterprise

Intermittent: 12 units
This is a project course for senior business majors offered in partnership with real-world client companies; students must apply for the course and enrollment is by special permission. Students will learn about the challenges of the multi-dimensional and complex issues faced by managers, including learning the concepts and skills to handle ambiguity, perform a persuasive data analysis, and communicate the findings effectively. Students will develop a deeper understanding of how organizations can co-ordinate and leverage synergies across a range of disciplines by effective deployment of technologies and organizational structures and processes. Teams will have an opportunity to work with clients on a wide mix of problems spanning multiple functions, including strategy, operations, technology and marketing. Specifically, teams will address issues such as big data, mobile application strategies, supply chain, digital media, complexity management, health care delivery models and healthcare marketing strategy. Regular meetings with the instructor will be scheduled to guide teams during client engagement and co-ordinate with the executives at their client company. The deliverables will be in the form of a report/prototype and a final presentation to the client's executive team. No classes to attend, but weekly team meetings with times to be determined. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 70-391 and 70-122 and 70-311 and 70-371 and 70-381

70-449 Social, Economic and Information Networks

Spring: 9 units
Interaction is a fundamental part of social science: firms market products to consumers, people share opinions and information with their friends, workers collaborate on projects, agents form alliances and coalitions. In this course, we will use the emerging field of social networks to put structure on this diverse mass of connections. Using a mixture of theoretical, empirical, and computational methods, we will learn about the structure and function of social networks. We will look at how an individual's position in a social network reflects her role in the community. We will learn to identify tastemakers and trendsetters by looking at how information moves through our increasingly connected society. We will consider how our own position in the social network affects our behavior, opinions, and outcomes. And we will explore where social networks come from, and what affects their structure. The material in this course will be interdisciplinary, drawn from the fields of math, computer science, physics, sociology, political science, and economics. By the end of the course, you will have the tools and knowledge needed to analyze social networks on your own. The course is capped with a project where you will use your skills to answer your own questions. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: (36-201 or 73-230 Min. grade C or 36-200) and (36-207 or 70-207 or 36-201)

70-452 Introduction to Product Management

All Semesters: 9 units
This course introduces the role and responsibilities of the Product Manager in a technology-intensive product or services company. The over-arching goal of the course is to give you the knowledge and tools you need to make good product decisions so that your team can ship the right product, to the right customers, through the right channels, at the right price. To that end, you will learn to apply tools and techniques for building and managing a product roadmap, prioritizing development requests, evaluating tradeoffs, and modeling the financial implications of different business models, operating models, pricing, and packaging options. Along the way, we will look at many of the core activities and tasks that an effective Product Manager needs to master, including:Understanding value propositions and customer priorities, Identifying and selecting customer and market segments, Packaging and bundling capabilities and benefits into a cohesive set of offerings, Selecting pricing models and setting specific prices, Estimating the likely benefits and costs of proposed product enhancements, Modeling and evaluating the financial implications of product choices, Managing the full product life cycle, from conception to sunsetting. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.

70-453 Business Technology for Consulting

Intermittent: 9 units
In this course, you will learn to how to effectively lead and undertake information system analysis and design projects. In doing so you will develop your 'intellectual toolbox' for business technologies consulting by learning to apply specific tools and techniques such as BPMN and Agile development methodologies. You will practice applying these techniques on a variety of case studies, examples, and a substantial semester-long project. Beyond the concrete analysis and design techniques, you will develop a set of work practices and habits of thought that should serve you well in your consulting career. This will be a very hands-on course in which you will largely learn by doing. Most class sessions will include a combination of some presentation by the instructor, some discussion (possibly of a case study), and exercises to practice working with the day's tools and concepts. Homework assignments, in-class presentations, and a semester-long term project are essential parts of the course.
Prerequisites: 70-451 or 70-110

70-455 Data Management Fundamentals

Intermittent: 9 units
Data drives modern business. Transactional data systems keep the world's economy operating smoothly by tracking and processing the movement of bits, money, atoms, and attention across the planet. Analytic systems help managers understand and optimize their businesses. Robotic systems (both physical machines and software bots) are automating a tremendous amount of the work that has historically been done by people. In this course you will learn to use a set of data management tools to capture, manage, analyze, and understand data so to help your organization do business better, faster, and cheaper. This course was previously titled Modern Data Management. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 15-112 or 70-110 or 15-110 or 15-104

70-458 Advanced Data Management

Intermittent: 9 units
There's a lot of data out in the world. _A_LOT_. It's not only being generated, captured, stored, and analyzed at a rate unlike anything seen in human history, but the rate at which all of this is happening is accelerating. Rapidly. For better and for worse, a lot of this data does not fit nicely into the clean, precise, and carefully structured tabular formats perfected by computer scientists and IT professionals in the latter part of the 20th century. Rather, this data (you've probably heard it called "Big Data", "Unstructured Data", "Loosely-Structured Data", "4k Video", etc.) comes in all sorts of shapes and sizes, and in volumes that are so large they require new ways of thinking about capturing, managing, and working with it. In this course, you will learn to work with big, loosely-structured data sets to better understand the world and make better decisions as you operate within it. We will explore a wide variety of different approaches to representing data (graphs, data documents, and lt;key,value and gt; pairs, geo-polygons, Big Tables, massive text indices, etc.) and the tools that use those data stores to uncover insights and help you make good business decisions. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisite: 70-455

70-460 Mathematical Models for Consulting

Intermittent: 9 units
This course will cover a wide variety of mathematical models and techniques that are used by consultants and lie at the heart of modern decision-support systems. We will discuss the benefits and limitations of different models and follow a practical spreadsheet-based approach to provide hands-on experience with Excel Solver. The course will build on the knowledge you have gained from the prerequisite courses; we will develop your model-building skills, explore some technique-oriented skills such as linear, integer, and nonlinear programming, and experiment with heuristic solution methods. While going through different models and techniques, we will also see real-world examples of how these models are actually used in practical business environments. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 21-292 or 21-257 or 70-257

70-462 Uncertainty and Risk Modeling

Intermittent: 9 units
This course takes the perspective of the consultant whose job is to analyze existing or potential business processes and provide recommendations for managerial decision-making. Recognizing that most businesses are subject to high levels of variability, risk and uncertainty, it will adopt a stochastic approach to characterize the behavior of business systems and processes, and explore the effects of alternative decisions in this context. Two modeling methodologies will be covered: (i) stochastic modeling, and (ii) stochastic simulation. Examples are drawn from different managerial domains, such as supply chain management, risk management, marketing, and project management. The lectures, homework assignments, exam and term project will focus on modeling, computational, and analytical skills. Computational implementations will be done in Excel using the @Risk add-in (during the first half of the course to build simple simulation models) and the Arena software (during the second half of the course to build more complex models based on discrete-event simulation). This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 36-220 or 36-225 or 36-200 or 36-201 or 36-207 or 70-207

70-465 Technology Strategy

Intermittent: 9 units
This course is about business strategy for technology-intensive industries. Examples of such industries are computer hardware and software, media and entertainment, telecommunications and e-commerce. We will explore the unique economic circumstances facing firms in these industries and identify strategies that enable firms to succeed given these circumstances. You will learn to analyze pricing strategies including versioning and bundling; product standardization decisions; managing product complements; exploiting network effects; managing platform competition. This course will help you understand the unique economic characteristics seen in today's technology-intensive markets and how they impact the strategic interactions among firms and consumers. We will study, for example: Why firms in the IT industry give away their best products for free. Why makers of video gaming consoles subsidize end users (but tax game developers) while computer operating system makers subsidize software developers (but overcharge end users). Why Sony won the Blu-Ray format war against HD-DVD which was sponsored by a whole array of companies. In order to understand how firms strategically interact with consumers in technology-intensive industries this course will use a combination of simple but rigorous analytical models, emerging theories, and formal case studies.
Prerequisites: 21-120 and (21-259 or 21-256) and 73-100 and 73-230

70-467 Machine Learning for Business Analytics

Intermittent: 9 units
This course introduces students to the machine learning tools and software that drive modern predictive analytics in business settings. Students will gain an understanding of a variety of popular machine learning algorithms including linear and logistic regression, random forests, and neural networks. Each algorithm will be introduced with real-world business applications, and students will learn to implement these algorithms on data. The course is taught in the programming language R (prior programming experience is not required).This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: (21-254 or 21-259 or 21-256) and (36-220 or 36-225 or 36-200 or 70-207)

70-469 End to End Business Analytics

Intermittent: 9 units
Deriving value from business data is an integrative process. It requires putting together the virtuous pipeline of using the data to derive descriptive and diagnostic inferences, building explainable predictive models and incorporating them in prescriptive decision making. This course charts this process end-to-end by describing and integrating common tools for modeling uncertainty, machine learning, and optimization in the context of common applications from finance, marketing and operations. The coursework is based on data-driven cases that will have students analyzing data from real business applications to derive their own insights, predictions and decisions and communicating them effectively. The course will prepare students for careers in consulting and any form of business data analysis in any functional area. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: (36-200 or 36-225 or 70-207 or 36-220) and (21-257 or 21-292 or 70-257)

70-471 Supply Chain Management

Intermittent: 9 units
This course will discuss basic issues in supply chain management to answer how a company should design its supply chain and how a company should administer its operations policy to satisfy the company's business strategy. We will also examine how firms interact with other entities within the supply chain, and how one can turn the system/network of entities across the supply chain to its own advantage by capturing economic surplus effectively. Special attention will be paid to analyzing the strengths and weaknesses of supply chains from a strategic, qualitative level. At the same time, we will also learn how to make effective trade-offs in operational decisions from a tactical, quantitative level. This course uses course material that requires students to pay an additional course fee. The course material is secured by the Tepper School because it is otherwise unavailable and directly provided to each student.
Prerequisite: 70-371

70-477 Real Options: Creating Value Beyond NPV

Intermittent: 9 units
Real options analysis is an approach to the management of operational assets that exploits managerial flexibility in decision-making and combines it with market-driven valuation of cash flows. It is thus particularly useful when managing projects that involve dynamic and state-contingent choices among alternatives (options), especially of a strategic nature. The valuation of financial options is the conceptual basis of real options management (but this course does not assume prior knowledge of this topic). Real options analysis extends this fundamental market-driven valuation approach to a much broader spectrum of business applications that feature dynamic decision-making. It thus contrasts the standard net present value rule used by static discounted cash flow analysis. The resulting managerial decisions and asset valuations can be very different when real options analysis is used rather than static discounted cash flow analysis. The course learning objectives are to (i) develop the students ability to take an unstructured problem and implement real options analysis in a structured manner; (ii) integrate market-driven valuation and dynamic decision-making techniques into a practical, yet rigorous, business analytics toolkit; and (iii) provide examples of successful practice and applications in a variety of industries. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.

70-480 International Marketing

Intermittent: 9 units
This course is designed to provide students with a basic understanding of global marketing opportunities, key issues, and strategies. It introduces the main characteristics of international markets and addresses the impact of global environmental factors (economic, social, legal, and cultural) on marketing decisions such as market entry, product development, pricing, promotion, and distribution. The objective of the course is to help students acquire knowledge of major international marketing concepts and develop cross-cultural sensitivities and skills that would enable them to identify, analyze, and solve international marketing problems. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.

70-481 Marketing Research

Intermittent: 9 units
The purpose of this course is to teach multiple research techniques used in marketing. This course is an applied marketing course that gives insight into how various techniques are used in marketing research firms. There are three projects and a final. The first project is designed to teach students about research survey methods. The second is an experiment in which the whole class is involved. The third, an individual project, is designed to teach quantitative research techniques. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: (36-202 or 70-208) and 70-381

70-482 Pricing Strategy

Intermittent: 9 units
Pricing is a critical marketing decision which enables a firm to translate customer value into profit. This course provides a first survey of pricing concepts. Instead of discussing pricing in isolation, we focus on the interplay between pricing and other aspects of marketing, such as positioning, branding and advertising. To this end, we provide a formal treatment of pricing concepts in the framework of game theory. Finally, we also discuss non-pricing tools that firms can use in order to capture customer value. Specifically, we cover cases wherein firms generate a profit while keeping their services free, a phenomena that is widely observed among Internet firms. This course has no formal prerequisite, but a willingness to study formal (i.e., mathematical) models is assumed. Any previous exposure to microeconomics analysis and game theory will be helpful. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.

70-483 Advertising and Marketing Communications

Intermittent: 9 units
It is critical that marketers understand the limitations of marcom tactics as well as how to best leverage and integrate marcom tactics for the strongest, most consistent and authentic brand voice in the targeted marketplace. The entire IMC process is driven by the customer, and in the case of our discussions in this class, the consumer. The course is designed to help students understand the integrated marketing communications model, the strategy and tools of the marketing mix and what makes an iconic brand. The course is designed in five sections: Part One focuses on understanding brands - iconic brands, terminology and types of branding. Part Two focuses on the understanding of consumer behavior - one of the, if not the most critical part of understanding marketing. Brands are built and defined in the minds of consumers. Part Three focuses on IMC and the framework used by brand management to develop strategy, and understand audience segmentation and brand positioning to drive IMC. Part Four focuses on understanding the IMC tactics available to marketers including advertising, social media and digital marketing, events and public relations. Part five concludes with the deeper study of an iconic brand. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisite: 70-381

70-484 Data Science for Finance

Intermittent: 9 units
This course first reviews the fundamentals of Financial Data Science with Python. The course then introduces several financial applications that rely heavily on data analytics, including 1) Algorithmic Trading, 2) Quantitative portfolio management, and 3) "Smart" beta and performance analysis. The class uses tools from statistics, machine learning and natural language processing. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 70-391 and (36-202 or 36-208 or 70-208)

70-485 Product and Brand Management

Intermittent: 9 units
Product managers are essentially the "CEO" of the product line. Brand and product management provides strategic vision and leadership for the product and service, both 1) understanding the market opportunity and what must be done for successfully delivering on the brand promise and 2) leading across the organization, often without authority, to achieve that success. Product/service success in a dynamic market is subject to many factors, including marketplace needs, reactions and activities of competition, the strategy and change within one's own firm, operating and financial constraints, demand forecast uncertainty, and more. By taking this course, you will learn the principles of product and brand management and understand what it is like and what it takes to be a successful marketing leader. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisite: 70-381

70-488 Marketing Digital Media

Spring: 6 units
(Formerly titled "Interactive Marketing") In this course we analyze how marketing practice changes when products are distributed and consumed in digital formats. This course focuses on several areas where digitization is likely to have the most profound affect on the field of marketing. These areas include promotion, competitive strategy, channel conflict, pricing, and identifying and differentiating customers. We will use both lectures, cases, and analysis of real-world datasets to analyze these issues.
Prerequisite: 70-381

70-490 Big Data in Finance and Machine Learning

Spring: 12 units
This course deals with the financial decisions of corporations. The focus is on learning through ?hands-on? experience of the corporate world, supplemented by a discussion of theoretical concepts and analysis of data. This ?hands-on? experience is in computerized lab games that simulate the corporate world, in which students participate as CEO?s, investors, and directors. Topics to be covered include the following: dividend policy; financial reporting; CEO compensation; and valuation. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 70-391 and 70-122

70-492 Investment Analysis

Intermittent: 9 units
Investment analysis provides you the concepts and tools used to analyze publicly traded securities, and you will learn how to these tools to real world situations. The course is organized as a tour of the different kinds of securities used in the financial markets. You will analyze how security prices are determined, the relations between the prices of different securities, their risks and returns, and how to choose a portfolio or strategy from different asset classes. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 21-370 or 70-391

70-493 Valuation and Financial Modeling

Intermittent: 9 units
This course focuses on valuing companies. Students will learn theoretical valuation frameworks and then apply them practically. The class will cover a range of valuation approaches including discounted cash flow analyses, price multiples, real options and the venture capital method. The class will be very hands-on - we will be building valuation models in excel in-class and in case assignments using real-world data such as company financial statements and stock prices. This is particularly useful for students considering careers in investment banking and private equity. We will focus not just on learning valuation methods but also understanding the assumptions that underlie them. We will ask when such assumptions are trivial and when they can lead to large errors. We will value a variety of companies including Ferrari, WhatsApp and Snap Inc. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisite: 70-391

70-495 Corporate Finance

Spring: 9 units
Students develop an advanced financial perspective on how firms make investment, financing, and management decisions. The course starts with simple net present value rules and builds the theoretical framework to address more sophisticated issues and problems including risk management, mergers, acquisitions, executive compensation, corporate governance, and dividend payout policies. Theory is supplemented with numerous case study examples. This course uses course material that requires students to pay an additional course fee. The course material is secured by the Tepper School because it is otherwise unavailable and directly provided to each student.
Prerequisites: 70-391 or 21-370

70-497 Derivative Securities

Intermittent: 9 units
This course has two goals. The first goal is to help you to master the tools to price and hedge and understand the risk exposures of any contingent claim on any underlying variable. The second goal in this course is to practice using these pricing and hedging tools in derivative structuring and sales. The focus here is on designing and pricing derivative securities to trade on specialized market views and to hedge customized risk exposures. The course also highlights practical issues about model calibration, model risk, and dynamic and static hedging. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: 70-391 or 21-370

70-498 Business Language Analytics: Mining Financial Texts and Graphs

Spring: 9 units
This course provides students with accounting concepts and tools to create structures in financial data and some hands-on experience in applying economic, statistical, and data- mining tools to analyze corporate business language, both text and numbers, used in formal documents written following specific accounting language rules. Accounting numbers: Accounting numbers such as those in published corporate financial statements obey a basic double-entry bookkeeping structure leading to a matrix or graph representation beyond the typical numerical data structure. After a basic introduction of using corporate financial data, much of the course covers the concepts and tools that process corporate accounting data using the graph representation. Accounting texts: While texts in accounting documents are written in natural language, they must obey regulatory disclosure requirements in both substance and form. The remaining part of the course shows students how data in text form from accounting disclosures such as annual reports can be examined systematically using textual analysis techniques to gain further insight and knowledge about firms and industries beyond those inferred from non-textual data. This course may use third-party copyright material. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisite: 70-122

70-499 Internship

Fall and Spring: 3 units
Students doing a business-related internship for academic credit may enroll in this course for three units with a pass/no pass grade. Students must submit an internship agreement form to the instructor for approval prior to the start of the internship. A summary writing assignment must be submitted after the internship in order to receive credit. Enrollment with special permission. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.

70-500 Honors Thesis I

Fall and Spring
Business students with outstanding academic records may undertake an Honors Thesis. The topic is of the student's choice but must have some original aspect in the question being explored, the data set, or in the methods that are used. It must also be of sufficient academic rigor to meet the approval of a faculty advisor with expertise in the project's area. Students enroll each semester in a 9-unit independent study course with their faculty advisor for the project (70-500 in the fall and 70-501 in the spring). Students and their faculty advisor develop a course description for the project and submit it for approval as two 9-unit courses to the BA department. Enrollment by permission of the BA Program.

70-501 Honor Thesis II

Fall and Spring
Business students with outstanding academic records may undertake an Honors Thesis. The topic is of the student's choice but must have some original aspect in the question being explored, the data set, or in the methods that are used. It must also be of sufficient academic rigor to meet the approval of a faculty advisor with expertise in the project's area. Students enroll each semester in a 9-unit independent study course with their faculty advisor for the project (70-500 in the fall and 70-501 in the spring). Students and their faculty advisor develop a course description for the project and submit it for approval as two 9-unit courses to the BA Director. Enrollment by permission of the BA Program.

Undergraduate Economics

Oliver Hahl, Associate Dean, Undergraduate Programs; Associate Professor of Organization Theory, Strategy and Entrepreneurship

Jennifer Wegner, Assistant Dean, Undergraduate Programs

Location: Tepper Quad, Suite 2400

Email: uba@andrew.cmu.edu

Advising Appointment Online Scheduler: https://meetme.so/TepperAdvising

At its most fundamental level, economics is the study of how scarce resources are allocated. What will be produced and consumed, how much, and by whom? These questions are central to the well-being of people throughout the world. Economists identify, model, and analyze problems with the objective of developing practical and efficient solutions to challenges confronting society. Economists are also active participants in the processes and institutions through which economic policies are implemented. In the public arena sphere, economists contribute to the design of programs and incentive systems to foster efficient implementation of policies. In the private sector, economists use modeling and data-analytic skills, both in identifying ways to enhance productive efficiency within the firm and in developing strategies to enhance effectiveness of the firm as it competes in the global marketplace.

Upon major declaration, students pursuing the Bachelor of Arts in Economics or Bachelor of Science in Economics are affiliated with the Tepper School of Business. This means that students complete the Tepper general education requirements and are subject to all Tepper School policies and procedures. Students interested in the Bachelor of Science in Economics+Mathematics first declare the Bachelor of Science in Economics degree and are then able to apply for Economics+Mathematics major. The academic college affiliation for students pursuing majors in Economics +Politics and Economics+Statistics is the Dietrich College of Humanities and Social Sciences.

EDUCATIONAL OBJECTIVES

The Economics majors are designed to develop strong analytical skills and a solid foundation in the discipline of economics. More specifically, measurable objectives for our economics curriculum are the following:

- Students should be able to identify, explain, and use economic concepts, theories, models, and data-analytic techniques.
- Students should acquire and use knowledge of economics, mathematics, statistics, and computing flexibly in a variety of contexts, providing the foundation for success in graduate studies and careers in the public and private sectors.
- Students should be able to apply their economic tools to formulate positions on a wide range of social and economic problems and engage effectively in policy debates.
- Students should use the investigative skills necessary for conducting original economic research and participating effectively in project teams.
- Students should be able to deliver effective presentations in which they combine visual communication design with oral arguments and/or the written word.

Degree Options

In order to accommodate students' wide variety of goals, three primary degree majors are available in the Tepper School of Business:

- Bachelor of Arts in Economics
- Bachelor of Science in Economics
- Bachelor of Science in Economics and Mathematical Sciences (jointly administered with the Department of Mathematics)

The Dietrich College of Humanities and Social Sciences administers two interdisciplinary Economics majors:

- Bachelor of Science in Economics and Politics
- Bachelor of Science in Economics and Statistics

Additional majors in Economics, Economics and Politics, and Economics and Statistics, and a minor degree program in Economics are available for Carnegie Mellon students.

FIRST YEAR ACADEMIC ADVISING

First-year students interested in Economics begin in Dietrich College and are assigned a Dietrich College Academic Advisory Center (http://www.cmu.edu/hss/advisory-center/) (AAC) advisor. While the AAC advisors are the advisors of record until students formally declare their majors, students who are considering majoring in Economics are encouraged to speak with the Tepper School Economics advisors so that they will have access to program resources, advising, and the community of faculty, staff, and students.

B.A. in Economics

To receive the B.A. degree in Economics, students must complete at least 360 units, consisting of the requirements for Mathematics, Quantitative Analysis, Economic Core, Economic Electives, Senior Requirement, University Core, and a Minor.

Mathematics Prerequisites

Courses		Units
21-120	Differential and Integral Calculus	10-20
or 21-111 & 21-112	Calculus I and Calculus II	
21-256	Multivariate Analysis	9-10
or 21-259	Calculus in Three Dimensions	

Economic Theory Requirements

		Units
73-102	Principles of Microeconomics	9
or 73-104	Principles of Microeconomics Accelerated	
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9
70-340	Business Communications	9
70-345	Business Presentations	9

Quantitative Analysis Requirements

		Units
70-207	Probability and Statistics for Business Applications	9
or 36-200	Reasoning with Data	
73-265	Economics and Data Science	9
73-274	Econometrics I	9

Economics Electives (36 Units)

Students must take four economics elective courses. Economics elective courses are those numbered 73-300 or higher.

Special Electives (18 Units)

Students must take two special elective courses. Students should consult the degree audit system for courses that satisfy the special electives requirement.

Course List

Sample List of Special Elective Courses		Units
19-402	Telecommunications Technology and Policy for the Internet Age	12
19-403	Policies of Wireless Systems	12
19-411	Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech	9
19-421	Emerging Energy Policies	9
19-425	Sustainable Energy for the Developing World	9
66-221	Topics of Law: Introduction to Intellectual Property Law	9
79-245	Capitalism and Individualism in American Culture	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-266	Russian History and Revolutionary Socialism	9
79-280	Coffee and Capitalism	9
79-283	Hungry World: Food and Famine in Global Perspective	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-300	Controversial Topics in the History of American Public Policy	9
79-315	The Politics of Water in Global Perspective	9
79-320	Women, Politics, and Protest	9
79-343	Education, Democracy, and Civil Rights	9
79-383	The History of Capitalism	9
80-136	Social Structure, Public Policy & Ethics	9
80-249	AI, Society, and Humanity	9
80-305	Game Theory	9
80-324	Philosophy of Economics	9
80-335	Social and Political Philosophy	9
80-348	Health, Human Rights, and International Development	9
84-310	Policy in a Global Economy 1: International Trade and Trade Policy	9
84-318	Politics of Developing Nations	9
84-362	Diplomacy and Statecraft	9
84-387	Remote Systems and the Cyber Domain in Conflict	9
88-411	Rise of the Asian Economies	9

Senior Work

		Units
73-497	Senior Project	9
or 73-500 & 73-501	Tepper College Honors Thesis I and Tepper College Honors Thesis II	

Note: Students in the BA in Economics who complete an Honors Thesis in economics may use 73-497 (Senior Project) as an economics elective.

MINOR

In order to obtain the degree, students must complete a minor from another academic department. For students electing to complete an additional major or dual degree, the minor is waived.

UNIVERSITY CORE

Students are required to complete the Tepper University Core, general education coursework in the liberal arts and sciences.

COMPUTING @ CARNEGIE MELLON

All undergraduate students are required to take 99-101 (http://coursecatalog.web.cmu.edu/search/?P=99-101) Computing @ Carnegie Mellon to graduate (usually taken prior to the start of the first year or during the first year). The course focuses on Carnegie Mellon tools and technologies.

B.S. in Economics

To receive the B.S. degree in Economics, students must complete at least 360 units, consisting of the requirements for Mathematics, Quantitative Analysis, Economic Core, Economic Electives, Senior Requirement, University Core, and a Minor.

Mathematics Requirement

		Units
21-120	Differential and Integral Calculus	10-20
or 21-111 & 21-112	Calculus I and Calculus II	
21-256	Multivariate Analysis	9
or 21-259	Calculus in Three Dimensions	
21-240	Matrix Algebra with Applications	10
or 21-241	Matrices and Linear Transformations	

Quantitative Analysis Requirements

		Units
73-265	Economics and Data Science	9
73-274	Econometrics I	9
73-374	Econometrics II	9
or 73-423	Forecasting for Economics and Business	
or 70-467	Machine Learning for Business Analytics	

Economic Core Requirements

		Units
73-102	Principles of Microeconomics	9
or 73-104	Principles of Microeconomics Accelerated	
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9
70-340	Business Communications	9
70-345	Business Presentations	9

Economics Electives (54 Units)

Students must take six economics elective courses. Economics elective courses are those numbered 73-300 or higher.

Senior Requirement

		Units
73-497	Senior Project	9
or 73-500 & 73-501	Tepper College Honors Thesis I and Tepper College Honors Thesis II	

Note: Students in the BS in Economics who complete an Honors Thesis in economics may use 73-497 (Senior Project) as an economics elective.

MINOR

In order to obtain the degree, students must complete a minor from another academic department. For students electing to complete an additional major or dual degree, the minor requirement is waived.

UNIVERSITY CORE

Students are required to complete Tepper University Core, general education coursework in the liberal arts and sciences.

COMPUTING @ CARNEGIE MELLON

All undergraduate students are required to take 99-101 (http://coursecatalog.web.cmu.edu/search/?P=99-101) Computing @ Carnegie Mellon to graduate (usually taken prior to the start of the first year or during the first year). The course focuses on Carnegie Mellon tools and technologies.

B.S. in Economics and Mathematical Sciences

The B.S. in Economics and Mathematical Sciences is an interdisciplinary major that provides students with courses that complement and develop depth of understanding of economic theory, applied economics, and applied mathematics. The major equips students with the mathematical tools that are essential for success in Ph.D. programs in economics, mathematics, and key functional areas of business including finance, accounting, marketing, and information systems. Students must be enrolled in the B.S. in Economics major to apply for the Economics and Mathematics major. Acceptance into the major is based on meeting the following requirements:

- Cumulative QPA of at least 3.5
- Earned a "B" or better in 21-127 Concepts of Mathematics or 21-128 Mathematical Concepts and Proofs
- Earned a "B" or better in 21-241 Matrices and Linear Transformations
- Completed Principles of Microeconomics waiver, 73-102 Principles of Microeconomics or 73-104 Principles of Microeconomics Accelerated
- Earned a "B" or better in 73-103 Principles of Macroeconomics
- Earned a "B" or better in either 73-230 Intermediate Microeconomics or 73-240 Intermediate Macroeconomics
- Personal statement

B.S. in Economics and Mathematical Sciences

Economic Theory Requirements

		Units
73-102	Principles of Microeconomics *	9
or 73-104	Principles of Microeconomics Accelerated	
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9

Quantitative Analysis Requirements

		Units
70-207	Probability and Statistics for Business Applications	9
or 36-200	Reasoning with Data	
36-225	Introduction to Probability Theory	9
or 36-235	Probability and Statistical Inference I	
or		
or 21-325	Probability	
73-265	Economics and Data Science	9
73-274	Econometrics I	9
73-374	Econometrics II	9

Mathematical Sciences Requirements

		Units
21-120	Differential and Integral Calculus	10-20
or 21-111 & 21-112	Calculus I and Calculus II	
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	12
21-228	Discrete Mathematics	9-12
or 15-251	Great Ideas in Theoretical Computer Science	
21-241	Matrices and Linear Transformations	11
21-259	Calculus in Three Dimensions	9-12
or 21-256	Multivariate Analysis	
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
21-260	Differential Equations	9
21-355	Principles of Real Analysis I	9
21-356	Principles of Real Analysis II	9

Programming Requirement (10 Units)

		Units
15-110	Principles of Computing	10

Writing Requirement

		Units
70-340	Business Communications	9

Economic Electives (27 Units)

Students must take three economics elective courses. Economics elective courses are those courses numbered 73-300 through 73-495, (excluding 73-374 Econometrics II). Students are encouraged to work with their advisors to structure a set of courses which meet these requirements based on their particular interests, subject to course availability.

Recommended Economics Electives:

73-315	Market Design	9
73-338	Financial Crises and Risk	9
73-347	Game Theory Applications for Economics and Business	9
73-365	Firms, Market Structures, and Strategy	9
73-421	Emerging Markets	9

Mathematical Science Depth Electives (27 Units)

Students must take three advanced mathematics depth courses. Students are encouraged to work with their advisors to structure a set of courses which meet these requirements based on their particular interests, subject to course availability.

Recommended Mathematical Science Depth Electives:

21-270	Introduction to Mathematical Finance	9
21-292	Operations Research I	9
21-301	Combinatorics	9
21-341	Linear Algebra	9
21-369	Numerical Methods	12
21-370	Discrete Time Finance	9
21-371	Functions of a Complex Variable	9
21-393	Operations Research II	9
21-420	Continuous-Time Finance	9
21-484	Graph Theory	9

Note: Only one of the following courses may count towards the required Mathematical Sciences Depth Electives: 21-365 Projects in Applied Mathematics or 21-366 Topics in Applied Mathematics.

Senior Work (9 units; 18 units for students completing an honors thesis in economics)

73-497	Senior Project	9
or 73-500 & 73-501	Tepper College Honors Thesis I and Tepper College Honors Thesis II	

Note: Students in the BS in Economics and Math who complete an Honors Thesis in economics may use 73-497 (Senior Project) as an economics elective.

DOUBLE-COUNTING RESTRICTION

The 3 economics electives and 3 math electives cannot double count with another major or minor.

UNIVERSITY CORE

Students are required to complete University Core, general education coursework in the liberal arts and sciences.

COMPUTING @ CARNEGIE MELLON

All undergraduate students are required to take 99-101 (http://coursecatalog.web.cmu.edu/search/?P=99-101) Computing @ Carnegie Mellon to graduate (usually taken prior to the start of the first year or during the first year). The course focuses on Carnegie Mellon tools and technologies.

Additional Major in Economics

Students are eligible to apply for the Additional Major in Economics after completion of the Minor in Economics.

Mathematics Requirement

21-120	Differential and Integral Calculus	10
or 21-111 & 21-112	Calculus I and Calculus II	
21-256	Multivariate Analysis	9
or 21-259	Calculus in Three Dimensions	
or 21-254	Linear Algebra and Vector Calculus for Engineers	
21-240	Matrix Algebra with Applications	10
or 21-241	Matrices and Linear Transformations	

Quantitative analysis requirement

73-265	Economics and Data Science	9
73-274	Econometrics I	9
73-374	Econometrics II	9
or 73-423	Forecasting for Economics and Business	
or 70-467	Machine Learning for Business Analytics	

Economic Core Requirement

73-102	Principles of Microeconomics *	9
or 73-104	Principles of Microeconomics Accelerated	
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9
70-340	Business Communications	9
70-345	Business Presentations	9

If a student is pursuing the additional major and receives a prerequisite waiver for 73102, 9 additional units of elective course work (73-3xx or higher) is required.

Economics Electives Requirement (54 units)

Students must take six economics elective courses. Economics elective courses are those numbered 73-300 or higher.

73-497	Senior Project *	9
or 73-500 & 73-501	Tepper College Honors Thesis I and Tepper College Honors Thesis II	

Note: Students who complete an Honors Thesis in economics may use 73-497 (Senior Project) as an economics elective.

Double count restriction

Students pursuing the additional major may double-count two economics electives with any other major or minor requirements. There are no double counting restrictions between the additional major and a student's home college general education requirements.

Minor in Economics

Students are eligible to apply for a minor upon completion of two required courses for the minor wherein they earn a 2.0 QPA or higher in said coursework.

While there are no double counting restrictions between the minor and the student's home college general education requirements, 73-265 Economics and Data Science and the 3 economics electives must be unique for the minor and cannot double count with any other major or minor.

Mathematics Requirements

		Units
21-120	Differential and Integral Calculus	10-20
or 21-111 & 21-112	Calculus I and Calculus II	
21-256	Multivariate Analysis	9
or 21-254	Linear Algebra and Vector Calculus for Engineers	
or 21-259	Calculus in Three Dimensions	
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	

Economic Theory Requirements (27 Units)

		Units
73-102	Principles of Microeconomics *	9
or 73-104	Principles of Microeconomics Accelerated	
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
or 73-240	Intermediate Macroeconomics	

If a student is pursuing an economics minor and receives a prerequisite waiver for 73102, 9 additional units of elective course work (73xxx) is required to ensure 54+ units are met in the minor curriculum.

Quantitative Analysis Requirements (18 Units)

Students who have taken coursework in intermediate-level regression analysis and data visualization may petition to substitute 73-274 Econometrics I or 73-423 Forecasting for Economics and Business for 73-265 Economics and Data Science.

		Units
70-207	Probability and Statistics for Business Applications	9
or 36-200	Reasoning with Data	
or 15-259	Probability and Computing	
or 21-325	Probability	
or 36-218	Probability Theory for Computer Scientists	
or 36-219	Probability Theory and Random Processes	
or 36-220	Engineering Statistics and Quality Control	
or 36-225	Introduction to Probability Theory	
or		
73-265	Economics and Data Science	9

Economics Electives (27 Units)

Students must take three economics elective courses. Economics elective courses are those numbered 73-3xx through 73-49x. Students are encouraged to work with their economics advisor to structure a set of courses to meet these requirements based on their particular interests, subject to course availability.

Undergraduate Economics Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/) *each semester for course offerings and for any necessary pre-requisites or co-requisites.*

73-003 Transfer Credit

All Semesters
This number "holds" a place for an economics transfer credit courses so that these courses can be used in the academic audit system. Student receiving 73-003 credit have met the requirement of earning the equivalent of a "C" in their non-CMU economics course; however, have not earned the equivalent of a "B" which would provide credit for a CMU economics course equivalency.

73-060 Economics: BaseCamp

Fall: 3 units
This short course will launch you into the economics intellectual space and get you thinking like an economist. Through a series of presentations by some of CMU's great economics thinkers you will learn how economic reasoning harnessed to data can lead to better policy design and better business decision making. Presentations may cover the economics of bitcoin and crypto-currency, online market design, financial crises, the future of work, how to become involved in economics research, healthcare, the environment, and other topics. The presentations will be curated by one of CMU's research economists and there will be plenty of opportunities for discussion and debate. The course will also introduce you to the CMU approach to economics and map out the CMU economics major landscape.

73-065 Nudging Behavior in Business and Public Policy

Spring: 3 units
This course applies the insights of Behavioral Economics to inform business and policy decisions. A nudge encourages desired behavior by framing the decision or environment such that various cognitive processes and heuristics are engaged in favor of the desired outcome. The use of this branch of social science has been used successfully by the UK and US governments by the Behavioural Insights Team and Social and Behavioral Sciences Team, respectively. Nudges have also been used effectively by the United Nations, via UNICEF, to address and change a variety of behaviors such as gender violence and sanitation practices. In 2016 the Supreme Committee for Delivery and Legacy founded the Qatar Behavioral Insights Unit (QBIU) and it was incorporated as a foundation under the Qatar Financial Center in 2019. This foundation is known as B4Development (B4D) and would be of interest and importance to CMUQ students. One of the partners of B4D is the Qatar Foundation.

73-102 Principles of Microeconomics

Fall and Spring: 9 units
The course is an introduction to microeconomic principles and how to think like an economist. Market and policy outcomes are largely a function of individual decisions. These questions typically take the form: how much and what combination of things should I buy? When do we want businesses to go bust? Should the government fund student tuition? It's my hope that you'll also start to think about everyday questions from an economic lens: why were bicycles so hard to find this past summer? Is Uber surge pricing just a rip-off? Is illegal streaming bad for consumers? Throughout the semester, we will build a toolkit to allow us to understand how these decisions interact and explain market successes, market failures, and the role of government in the marketplace. Toward the end of the semester, we'll change a few underlying assumptions and address a variety of questions related to strategic interaction. Some of the topics we will begin to introduce include credible threats, commitment problems, and the strategic use of information. Not open to students who have received credit for 73-100. While there are no calculus pre-requisites for this course, students are encouraged to enroll in 73-102 after they've passed 21-111. (Lecture, 2 hours; Recitation, 1 hour).

73-103 Principles of Macroeconomics

All Semesters: 9 units
A one-semester course that teaches the fundamentals of macroeconomics. Students will learn how macroeconomic analysis can explain national economic activity and how government intervention might stabilize an economy. Topics include: defining and measuring national wealth, economic growth, credit markets, unemployment, interest rates, inflation, and the monetary system. Additional emphasis will be paid to: long-term economic development, political economy, financial crises and topics that are central to contemporary macroeconomic debates such as the impact of technological change, migration, and trade on the macroeconomy. Students will access macroeconomic databases, and then use basic statistics to describe and isolate empirical patterns in macro-data. Not open to students who have received credit for 73-100. (Lecture, 2 hours; Recitation, 1 hour).
Prerequisites: 73-104 or 73-102

73-104 Principles of Microeconomics Accelerated

Intermittent: 9 units
This course is a rigorous introduction to microeconomic principles and how to think like an economist. The students are expected to have a successful, prior exposure to fundamental concepts and therefore, the course is at a faster pace than its sister course, 73102, and covers additional topics. The questions typically take the form: What is the optimal consumption pattern for me as an individual? What is the profit maximizing pattern of labor and capital goods for a firm? When do we want businesses to go bust? Should the government fund student tuition? How can firms hire the best match for them? Whay kind of informational asymmetries exist in double-sided markets? It's my hope that the students start to think about everyday questions from an economic lens: Why were cars so hard to find during the pandemic? Is Uber surge pricing just a rip-off? Is illegal streaming bad for consumers? Throughout the semester, we will build a toolkit to allow us to understand how these decisions interact and explain market successes, market failures, and the role of the third parties in the marketplace. Some later topics include credible threats, commitment problems, and the strategic use of information. Knowledge of basic calculus as covered in 21-111 would be helpful for the students. Only students with an AP Microeconomics Exam score of 4 or 5 and qualifying IB/Cambridge Economics exam scores are eligible to enroll in this course. Students without exam credit should enroll in 73-102 Principles of Microeconomics.

73-111 Internship I

All Semesters
By permission of the Undergraduate Economics Program.

73-112 Internship II

All Semesters: 3 units
The goal of this course is for you to reflect critically and constructively on your internship and to help you identify a path that will allow you to build on your internship experiences. By permission of the Undergraduate Economics Program. Open only to declared Economics, Economics and Mathematical Sciences, Economics and Politics, and Economics and Statistics majors.

73-113 Internship III

All Semesters: 3 units
The goal of this course is for you to reflect critically and constructively on your internship and to help you identify a path that will allow you to build on your internship experiences. By permission of the Undergraduate Economics Program. Open only to declared Economics, Economics and Mathematical Sciences, Economics and Politics, and Economics and Statistics majors.

73-153 Economics and Society

Intermittent: 9 units
Our society faces several challenges. Climate change, inequality, social justice, AI and technology are among some of the big ones. In this class, we show how economics or the science of incentives can be used to tackle these challenges. We will talk about the tools needed to approach any challenge and talk about unintended consequences of policies that might seem like they should work. We describe the limits and benefits of markets and use these foundations to talk about the main challenges facing our society and how to address them.
Prerequisites: 21-120 or 21-111

73-155 Models, Math, and Markets

Spring: 9 units
The Markets, Models and Math (M3) course is designed to allow students to reflect on the thought processes that drive science, viewed through the lens of economics. While the economics focus will highlight the way economists use data and models to understand the economic phenomena we see in the real world, the course is also designed to add depth of understanding for students who major in some other discipline, for the simple reason that the things economists study touch on all aspects of human existence, whether it is understanding the cost-benefit trade-offs in architectural design, in the engineering of new products or production technologies, or understanding the grand arc of political discourse in history or the way it has shaped our laws.

73-158 Markets, Models, and Math

Spring: 9 units
The Markets, Models and Math (M3) course is designed to allow students to reflect on the thought processes that drive science, viewed through the lens of economics. While the economics focus will highlight the way economists use data and models to understand the economic phenomena we see in the real world, the course is also designed to add depth of understanding for students who major in some other discipline, for the simple reason that the things economists study touch on all aspects of human existence, whether it is understanding the cost-benefit trade-offs in architectural design, in the engineering of new products or production technologies, or understanding the grand arc of political discourse in history or the way it has shaped our laws. The course is also meant to introduce, in an intuitive way, the kinds of mathematical tools and reasoning that economists use, what the economic historian Philip Mirowski has called "the unreasonable efficacy of mathematics in economic analysis".
Prerequisites: 21-111 and 73-102 Min. grade C

73-199 Experiential Learning in Business and Economics

All Semesters: 3 units
Students will collaborate to create an economic newsletter called "Southwestern PA Economy in a Snapshot," a regional version of the well-known national version produced by the New York Fed (https://www.newyorkfed.org/ medialibrary/media/research/snapshot/snapshot_january2021.pdf?la=en). The newsletter will lay the groundwork for a regular online publication produced by Carnegie Mellon Economics, a combination of data analysis/visualization and economic commentary. The ultimate goal is for the newsletter to be a to-go economics document for policy makers and business leaders in Pittsburgh and the surrounding region. Students will use a combination of data science skills, computer programming skills, and a basic knowledge of the relevant economic data. They will produce a professional, co-authored report that will serve as a valuable resume item for future career prospects. They will form small teams, each of which will create an Economic Commentary that uses the newsletter's data to provide analysis of a contemporary economic issue that is important for the Pittsburgh region. During the tenure of the course, students will also acquire new skills in computer programming, data analysis and economics. The course will "contribute. to a broader body of knowledge" by obtaining, organizing and publicizing regional economic data where no such product currently exists. It will "identify and develop skills needed to approach and tackle a practical problem or issue." That is, students will take skills obtained in the single pre-req course (Principles of Macroeconomics) and combine them with skills that almost all 1st year students take in data analysis and produce a professional piece of economic analysis. They will see how their academic education can be applied in way that this useful to business people and policy makers.
Prerequisite: 73-102 Min. grade C

73-230 Intermediate Microeconomics

Fall and Spring: 9 units
This course builds on the Principles of Economics course. It focuses on the following topics: theory of the consumer, theory of the producer, perfectly competitive market equilibrium, imperfect competition, and market failures due to asymmetric information such as adverse selection and moral hazard. (Lecture, 3 hours; Recitation, 1 hour).
Prerequisites: (21-256 or 21-269 or 21-259 or 21-268 or 21-254) and (73-100 or 73-102 or 73-104)

73-240 Intermediate Macroeconomics

Fall and Spring: 9 units
Through macroeconomic models built upon microeconomic foundations, insights are developed into economic growth processes and business cycles. Topics include aggregation and measurement, national income, business cycle measurement, economic welfare theorems and social inefficiencies, the effect of government fiscal policy upon employment and productivity, and the relationship between investment, interest rates and economic growth. (Lecture, 3 hours; Recitation, 1 hour). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (73-100 or 73-102 or 73-104) and 73-103 and (21-259 or 21-254 or 21-256)

73-255 Independent Study in Economics

Fall and Spring
The Independent Study course in economics allows students to pursue their own research interests in any of a variety of topics in economics. A typical independent study course involves a semester long project under the supervision of an appropriate faculty advisor. The nature and scope of the project are determined by the student and faculty advisor; the project proposal must be approved by an Undergraduate Economics Program staff member. Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: 21-120 and 73-160 Min. grade C

73-258 Developing Blockchain Use Case

Intermittent: 6 units
Blockchains, or distributed ledger and consensus technologies, hold tremendous promise for improving markets and organically handling private, secure data. As CMU develops its own blockchain and token and #8212;-CMU Coin and #8212;-a central concern is to determine the set of applications that such technology would be most useful for. This course is designed for students to propose and, potentially, develop applications or use cases for a campus blockchain. http://tinyurl.com/cmucoincourse (http://tinyurl.com/cmucoincourse/) The course begins with a brief introduction to blockchain using Bitcoin as an example of a blockchain protocol. We will examine the market failure Bitcoin was intended to resolve as well as the role of cryptography and distributed systems in enabling this new technology to create societal value. The course will go on to discuss the boundaries of the role of cryptography in blockchain. Next, we will use these tools to evaluate existing, real-world blockchain use cases with an eye towards developing our own applications of these emerging technologies. Along the way, we will learn practical development skills in distributed ledger technologies to understand blockchain programming and application development. Finally, students will propose their own blockchain use cases for CMU's own proprietary blockchain. No formal prerequisites, but familiarity with programming is highly recommended.

73-265 Economics and Data Science

All Semesters: 9 units
This course is at the intersection of economic analysis, computing and statistics. It develops foundational skills in these areas and provides students with hands-on experience in identifying, analyzing and solving real-world data challenges in economics and business. Students will learn the basics of database and data manipulation, how to visualize, present and interpret data related to economic and business activity by employing statistics and statistical analysis, machine learning, visualization techniques. Students will also be taught a programming language suitable for data science/analysis. Databases will include leading economic indicators; emerging market country indicators; bond and equity returns; exchange rates; stock options; education and income by zip code; sales data; innovation diffusion; experimental and survey data and many others. Applications will include analyzing the effectiveness of different Internet pricing strategies on firm sales, the impact of taking online classes on a worker's earnings, the relationship between regional employment and trade policies; constructing investment risk indices for emerging markets; predicting employee productivity with machine learning tools; assessing health (sleep and exercise) improvements associated with wearable technologies (e.g. FitBit). Additionally, the course will provide students with communication skills to effectively describe their findings for technical and non-technical audiences. Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (15-259 or 36-219 or 36-200 or 36-247 or 36-225 or 36-220 or 21-325 or 36-218 or 36-217 or 36-207 or 36-202 or 70-207 or 36-201) and (73-102 or 73-104)

73-274 Econometrics I

Spring: 9 units
Data tools are important in guiding decisions and strategies for individuals, businesses, and policymakers. This course will prepare you for data-driven decision making, providing both theoretical backgrounds and empirical illustrations of the techniques that are necessary to cope with real-world (imperfect) data. Specifically, the course covers tools and methods for estimating economic relationships, testing economic theories, and evaluating business and government policy. This course builds on either of the two Statistical Reasoning courses (36-200/201) and the Economics and Data Science course (73-265), and it sets underpinnings for Econometrics II (73-275) for more advanced tools and insights for business and economics data analyses. Students pursuing the ECOMTH or MTHECO degrees may enroll in 73-274 after the completion of 36-225. Minimum grade of "C" required in all economics and statistics pre-requisite courses.
Prerequisites: (21-254 or 21-256 or 21-259 or 21-269 or 21-268) and 73-265 Min. grade C and (73-230 Min. grade C or 73-240 Min. grade C)

73-315 Market Design

Intermittent: 9 units
In this course, we consider the design of various market mechanisms. We learn the typical causes of market failures and why we need to design new markets. For each topic, we start with a case study of a problem, develop a theory to address it, and consider its possible solutions. The class is roughly divided into three parts: matching, auctions, and further topics. In the first part, we study markets where there is no money and no prices (matching markets). Instead, we have people preferences over possible matching outcomes. Examples include placing doctors in residency positions, assigning students to schools, and assigning kidneys to transplant patients. We will learn algorithms that have desirable theoretical properties and are often used in practice. In the second part, we consider the problem of allocating of single or multiple goods (a house, a painting, or the rights to a natural resource such as oil or timber) using auctions. We discuss how different types of auctions work in theory and practice. We will look at the auctions used in financial markets to sell treasury bills, the auctions used by Google, Microsoft and Facebook to sell advertising, and the auctions used by governments to sell radio spectrum licenses. In the third part, we consider further important topics of market design. We will look into problems of high-frequency trading, digital markets, the allocation of refugees among European countries, and proposals to fix market for carbon pollution permits. An important goal of the course is to show how recent achievements of game theory and mechanism design lead to important practical applications and to inspire you to use these ideas in your life and workplace. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-254 or 21-259 or 21-256 or 21-269 or 21-268) and 73-230 Min. grade C

73-327 Advanced Topics In Macroeconomics And Real Business Cycles

Intermittent: 9 units
For analysts and decision makers in a variety of positions, such as business managers and government policy makers, a thorough understanding of the economy as a whole helps to make well-informed decisions. Examples of important knowledge about the economy are its sources of growth, the main impulses that cause the economy to fluctuate over time and enter into booms and recessions, the way in which these impulses propagate over time, and the state of the economy in general. The main objective of this course is to lay the foundation for such an understanding and present a framework within which we can (and will) evaluate a variety of aggregate phenomena. Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-269 or 21-259 or 21-256) and 73-240 Min. grade C

73-328 Health Economics

Fall: 12 units
This course will teach the student to use economic analysis to understand critical issues in health care and and health policy. We will address issues such as the following: 1. What factors best explain the level and rate of growth of U.S. health expenditures? 2. Does the recent high rate of growth of U.S. health care expenditures make U.S. firms less competitive in international markets? 3. What are some of the likely consequences (intended and unintended) of the proposed reforms to Medicare? 4. Can physicians induce demand for their services? 5. What are the impacts of managed care on the health care system? 6. Do strong affiliations between physicians and health plans hurt competition? (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses. Junior standing required.
Prerequisites: 21-120 and (73-102 or 73-104)

73-332 Political Economy

Spring: 9 units
The Political Economy course looks at how groups within society organize for self-governance. The course will begin with an overview of the ways groups of individuals organize for collective action by examining different types of political institutions, the role these institutions play in different contexts, and the economic and strategic micro-foundations that give rise to these institutions. We will then examine the empirical evidence supporting this taxonomy, leading to a more detailed consideration of institutions that moderate social conflicts. The next part of the course examines basic results in social choice theory: the Condorcet paradox, Arrow's Impossibility Theorem, majority rule, median voter theories, and modern treatments of probabilistic voting models that allow for strategic behavior, misrepresentation of preferences, and policy manipulation. From this basis for understanding collective choice mechanisms, we will then examine how institutions foster cooperation, looking in detail at problems of public goods allocation, redistribution of income, the organization of clubs - interest groups and lobbying associations and #8212;in the private sector, and the organization of legislative activities in the public sector. In our examination of voting and electoral mechanisms, we will look at practical applications of the theory to problems of gerrymandering, voter suppression, and propaganda that feature prominently in contemporary political discourse.
Prerequisites: (73-160 Min. grade C or 73-230 Min. grade C) and (70-207 or 36-201 or 36-200)

73-336 International Energy Market and Sustainable Development

Intermittent: 3 units
This course teaches you about economics of the energy industry by looking at various energy markets. The global energy industry is now more than ever is pressured to be transformed by geopolitical tensions, concerns about climate change, and the mounting pressure for decarbonization. In this course we will discuss how economic decisions in the energy sector can align with principles of sustainability, ensuring that the industry's growth and practices do not compromise the well-being of future generations or harm the planet.

73-337 Business of Blockchain

Intermittent: 9 units
Economics and business strategy is fundamental for the design and development of blockchain use cases. This course will introduce students to foundational economic concepts to help them understand the role cryptocurrencies play in securing blockchains, how different ``tokenomics'' models impact cryptocurrency prices, the different means to create liquidity or resolve illiquidity in decentralized finance (DeFi) applications such as stablecoins, collateralized-lending, yield farming, or automated market making, the roles of Central Bank Digital Currencies, as well as models to evaluate the value-added of blockchain-based versus traditional business propositions. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from $13 to $75.
Prerequisites: (73-104 or 73-102) and 73-103

73-338 Financial Crises and Risk

Fall: 9 units
This course provides an in-depth examination of the causes of financial crises as well as what governments can do to prevent them or at least reduce their cost. The course is designed to to provide an understanding of individual attitudes towards risk and individual decision making about savings and investment under uncertainty, and to use this understanding to evaluate the various economic roles played by financial institutions in helping individuals manage risk, especially those roles which may lead to economic instability and crises. In addition, the course may cover bubbles and swindles, especially when these spillover to the broader macroeconomy; the role of information in banking in normal times and in bank runs; crisis resolution techniques; and the extensive history of attempts to improve regulation so as to reduce the frequency and cost of crises. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-269 or 21-268 or 21-254 or 21-256 or 21-259) and (73-102 Min. grade C or 73-104 Min. grade C) and 73-240 Min. grade C

73-341 Managing through Incentives

Intermittent: 9 units
We live in an exciting age of information and knowledge when inspiring employees within a firm becomes increasing important. Aligning the objectives of workers, managers, and owners by providing them with appropriate incentives becomes an emerging paradigm in the modern business world. In this course, we learn how to reason about incentives between managers and employees, between managers and owners, and within a team of co-workers. We cover a broad range of topics including objective and subjective performance measurements, relative performance evaluations, relational contracts, and executive compensation. The course relies on business case discussions, rigorous theoretical material, and numerous class activities. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-254 or 21-269 or 21-268 or 21-259 or 21-256) and (36-220 or 36-219 or 36-218 or 36-225 or 36-217 or 36-200 or 36-207 or 36-201 or 36-202 or 70-207) and 73-230 Min. grade C

73-347 Game Theory Applications for Economics and Business

Fall: 9 units
An introduction to the theory of non-cooperative games with an emphasis on economic applications. After an initial examination of two-person, zero-sum games, the notion of a Nash equilibrium in an n-person, non-cooperative game is considered. Existence of and refinements to the equilibrium concept are discussed in the context of both normal and extensive form games. Economic applications may include various topics, including Cournot and Bertrand oligopoly models, general competitive exchange equilibrium, and free rider problems. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

73-348 Behavioral Economics

Spring: 9 units
This course introduces students to behavioral economics which is a subfield of economics that incorporates insights from other social sciences, such as psychology, into economic models and aims to explain the anomalies challenging some of the classical economic models. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (36-200 or 36-225 or 36-207 or 36-217 or 70-207) and 21-120 and (73-104 Min. grade C or 73-100 Min. grade C or 73-102 Min. grade C)

73-352 Public Economics

Fall: 9 units
In this course, students analyze the role of governments in market economies and their impact on the behavior and welfare of citizens. Reasons for government intervention in markets are examined in light of some of the economic challenges faced by modern societies in an increasingly globalized marketplace. Topics include: taxation and expenditure policies, externalities and market failure, social security, public assistance and income redistribution programs. There will also be some coverage of the role of local governments in the economy with respect to such issues as crime, urban development and education. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-254 or 21-256 or 21-259 or 21-269) and 73-230

73-353 Financial Regulation in the Digital Age

Spring: 9 units
The financial crisis and the digitalization of the financial markets have focused attention on the role of regulation for our financial system and the broader economy in recent years. Among the settings that are especially important in the digital economy are electronic trading, big data, algorithms, robo investing, winner-take-all economics, securities offerings, property rights and cyber assets. The course will address the foundations of regulation ("why regulate?") from various perspectives within a market economy, highlighting the sources of "market failure" (such as externalities, adverse selection, and natural monopoly) and potential remedies (such as disclosure, taxes and fees, antitrust prohibitions, privacy requirements, price regulation and guarantees). The conflicting goals among regulators (and why we have multiple regulators) and their impact on the meaning of regulation will be considered along with regulatory competition/arbitrage. Portions of the course will tackle relatively broad questions such as: Why regulate? Why could it be beneficial to restrict permitted algorithms? Are our markets rigged? How suitable are antitrust remedies in the digital era? What is the law of unintended consequences? What is the objective of a policy advocate? Are regulators and regulatory policies a systemic risk? How can regulators enhance the predictability and credibility of their policies? Should we bar insider trading? Should regulations be determined and motivated based upon cost-benefit analysis? How can we evaluate the success or failure of particular regulations and whether they have achieved their objectives? To what extent did the Dodd-Frank Act ensure financial stability?(Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-254 or 21-259 or 21-269 or 21-268 or 21-256) and 73-230 Min. grade C

73-359 Benefit-Cost Analysis

Intermittent: 9 units
The evaluation of public private sector projects. The theory of benefit-cost analysis and related techniques, such as cost-effectiveness analysis. Attention is given to such issues as valuing goods and services that are not normally traded in the marketplace (e.g., the value of an individuals life) and the social rate of discount. Applications are considered in detail. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (73-104 Min. grade C or 73-102 Min. grade C or 73-100 Min. grade C) and (36-225 or 36-220 or 36-217 or 36-207 or 36-200 or 36-202 or 70-207)

73-365 Firms, Market Structures, and Strategy

Fall: 9 units
This course is concerned with the economic analysis of industrial markets that are not perfectly competitive. The effects of imperfect competition on firms' decisions (pricing, location, advertising, research and development, among others) are reviewed. Implications of these effects in terms of public policy are also discussed from a variety of perspectives. Finally, applications to actual markets are considered. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-259 or 21-254 or 21-268 or 21-269 or 21-256) and 73-230 Min. grade C

73-366 Designing the Digital Economy

Spring: 9 units
This class analyzes the economics of e-commerce and technology. It will identify the critical features that differentiate the technology firms from traditional industries, and examine the implications for business strategy. The class will discuss topics such as network effects, switching costs, and platform markets. To complement the economic theory, we will also consider a case study of a firm each week. These have three aims: to provide applications for the concepts developed in the lectures; to inform you about different industries; and to help develop your written, rhetorical and presentation skills. Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-254 or 21-256 or 21-259 or 21-269 or 21-268) and 73-230 Min. grade C and (73-407 Min. grade C or 73-265 Min. grade C or 73-274 Min. grade C or 73-374 Min. grade C or 70-208 or 36-226 or 36-220 or 36-208 or 36-202)

73-369 Islamic Economics

Intermittent: 9 units
This course is designed to introduce students to the basics of Islamic Finance. The course will start with an analysis of the Shariah rules that define Islamic Finance. Students will then look at the main investment structures and map these against the traditional conventional banking products. The course wraps up with a critique of complex project finance structures through a Shariah compliance lens to identify the gaps between theory and practice.

73-374 Econometrics II

Fall: 9 units
The material covered in this course extends from the material covered in Econometrics I (73-274). The course will include both the theory behind the methods and a hands-on analysis of actual data, providing students the tools for both research and industry jobs. Theories and methodologies covered will include: nonlinear regression models, qualitative response regression models, panel data estimators, simultaneous-equation models, and time series. (Lecture, 3 hours; Recitation, 1 hour). Minimum grade of "C" required in all economics and statistics pre-requisite courses.
Prerequisites: (21-256 or 21-259 or 21-268 or 21-269 or 21-254) and 73-230 and 73-274

73-408 Law and Economics

Intermittent: 9 units
This course will provide a broad overview of the scholarly field known as "law and economics." The focus will be on how legal rules and institutions can correct market failures. We will discuss the economic function of contracts and, when contracts fail or are not feasible, the role of legal remedies to resolve disputes. We will also discuss at some length the choice between encouraging private parties to initiate legal actions to correct externalities and governmental actors, such aas regulatory authorities. Extensive attention will be given to the economics of litigation, and to how private incentives to bring lawsuits differ from the social value of litigation. The economic motive to commit crimes, and the optimal governmental response to crime, will be studied in depth. Specific topics within the preceding broad themes include: the Coase Theorem; the tradeoff between the certainty and severity of punishment; the choice between ex ante and ex post sanctions; negligence versus strict liability; property rules; remedies for breach of contract; and the American rule versus the English rule for allocating litigation costs. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: 21-120 and (73-102 Min. grade C or 73-104 Min. grade C)

73-415 Data Driven Business and Public Policy Decision Making

Intermittent: 9 units
In this course students will learn to leverage data to inform business and policy decisions. The course will teach students various methods for data description, including techniques of data visualization and statistical techniques. Students will learn how to assess the precision of estimation techniques. The final part of the course covers examples taken from epidemiology, economics, business and public policy. (Lecture, 3 hours: Recitation: 1 hour). Minimum grade of "C" required in all economics and statistics pre-requisite courses.
Prerequisites: (21-269 or 21-259 or 21-268 or 21-256) and 73-230 Min. grade C and 73-265 Min. grade C

73-421 Emerging Markets

Fall: 9 units
The goal of the course is to study the economic and institutional forces that spur or hinder business activity and growth in emerging economies. The course is designed to provide both quantitative and theoretical foundations for the study of emerging markets. On the quantitative side, the course will introduce students to the empirical analysis of the growth forces and obstacles facing emerging markets by providing numerous hands-on opportunities using real-world data. On the theory side, the course will provide an overview of fiscal, trade and exchange rate policies adopted in emerging economies. The course will focus on successful emerging economies such as India, China, S. Korea and Ireland with broader lessons and comparisons drawn from developed countries. The course will also look at distressed economies, such as North Korea and Venezuela analyzing the challenges and opportunities faced by these developing nations today. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (36-207 or 70-207 or 36-200 or 36-202 or 15-259) and (73-104 or 73-102) and 73-103

73-423 Forecasting for Economics and Business

Spring: 9 units
Governments forecast economic indicators (e.g., GDP, job growth, etc.); businesses forecast sales; portfolio managers forecast asset return; the list goes on. Accurate forecasts are critical to robust organizational decision-making. This course will introduce students to modern methods for forecasting in economic and business applications. Topics covered include Bayesian, statistical, and online learning approaches to forecast construction and assessment, univariate and multivariate time series models and algorithms, and principled combination of multiple methods and data sources along with subject matter expertise to improve performance. Methods will be motivated by applications in macroeconomics, technology, marketing, and finance, with cases drawn from forecasting processes in a variety of business and government organizations. Students will implement forecasting methods in R, including in a real data forecasting competition.
Prerequisites: (21-268 or 21-259 or 21-269 or 21-254 or 21-256) and (73-230 Min. grade C or 73-240 Min. grade C or 73-274 Min. grade C)

73-427 Sustainability, Energy, and Environmental Economics

Fall: 9 units
Topics related to sustainability and the environment are increasingly important to businesses, policymakers, and the general public. This course applies the tools of economic analysis to the problems of environmental protection, natural resource management, and energy production and use. The course will begin by introducing students to how an economist approaches problems of market failure commonly found in environmental contexts. Next, we will explore models that characterize solutions to such environmental issues. We will then address questions regarding measurement, policy design, and, finally, we will apply the tools that we have developed during the semester to the problems of climate change, and the optimal management of non-renewable resources. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (73-100 or 73-104 or 73-102) and (36-200 or 36-225 or 36-220 or 36-202 or 36-217 or 70-207 or 36-207)

73-436 Applied Projects for Business and Economics

Intermittent: 9 units
The Jewish Healthcare Foundation strives to make aging a joyful experience. With this vision in mind, a team of students will aim to conduct a market analysis in order to provide a report and presentation to the Foundation on areas such as policy, technology and/or infrastructure that counter aging mobility as a limiting factor. This exercise may cover a review of what exists in the aging space globally and/or specifically in the Pittsburgh community. Of note, in this project mobility may be defined broadly including areas such as transportation, physical limitations, use of technology etc.

73-469 Global Electronic Markets: Economics and the Internet

Fall: 9 units
The information revolution brought about by the Internet is having a dramatic impact on the organization of economic activity. Long-term contractual relationships that once governed corporate procurement are being dismantled as manufacturers use the Internet to market directly to the public. New transportation networks that used to simply move goods from point A to point B are evolving into dynamic inventory pipelines that allow manufacturers to track and even reroute shipments in real time. At the same time, individuals are making use of sophisticated search engines to comparison shop at a scale that would have been physically exhausting even five years ago. We will use the basic tools of economic analysis to understand how and why the changes in information technology are reshaping the economic landscape. (Lecture, 3 hours). Minimum grade standard of "C" applies only to economics courses.
Prerequisites: (21-268 or 21-256 or 21-259 or 21-269) and (73-230 Min. grade C or 73-160 Min. grade C)

73-476 American Economic History

Fall: 9 units
The study of economic history provides important perspective on current economic institutions and policies. A failure to understand the historical evolution of economic institutions or the variety of past economic experience is perhaps the worst shortcoming of many economists. The study of economic history provides an opportunity to test currently fashionable theories against data different from those used in their construction. In fact, this is a course in applied economics. The theories developed in the intermediate courses will be applied to episodes from the past in ways that increase understanding both of the specific historical episodes considered and the economic theories employed. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: 21-120 and (73-230 Min. grade C or 73-160 Min. grade C)

73-495 Advanced Independent Study in Economics

All Semesters
The Independent Study course in economics allows the student to pursue his or her own research interests in any of a variety of topics in economics. A typical independent study course involves a semester long project under the supervision of an appropriate faculty advisor. The nature and scope of the project are determined by the student and faculty advisor. Minimum grade standard of "C" applies only to economics courses.
Prerequisites: (21-259 or 21-269 or 21-256 or 21-268) and (73-230 Min. grade C or 73-240 Min. grade C)

Course Website: http://tepper.cmu.edu/prospective-students/course-page/73495/advanced-independent-study-in-economics (http://tepper.cmu.edu/prospective-students/course-page/73495/advanced-independent-study-in-economics/)

73-497 Senior Project

Fall: 12 units
A fourth-year project course, open only to Economics primary and additional majors with Senior standing. The senior project is a capstone course in economics. The purpose of the course is to showcase the analytical and quantitative skills that you have acquired as an undergraduate at Carnegie Mellon. The course project should reflect some independent applied research that is genuinely your own work. Thus a "book report" or a "literature review" are not sufficient exercises to satisfy this requirement. The following research approaches are acceptable for the research project: an empirical study based on a data set that you put together, an experimental study based on an experiment that you conducted, an analysis of survey data based on a survey that you conducted, a theoretical analysis based on a model that you have developed, based on your own algorithm. Students who write an honor thesis are exempted from this class. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.
Prerequisites: (21-268 or 21-259 or 21-256 or 21-269 or 21-254) and (73-274 or 73-265 or 73-407 or 73-374 or 36-303 or 36-226) and 73-230 and 73-240

73-500 Tepper College Honors Thesis I

Fall and Spring
Economics majors with outstanding academic records and intellectual promise will be given the opportunity to undertake original research under the direction of individual faculty members. Research topics are selected by students and approved by faculty. Prerequisites: Senior standing in the Economics Program and permission of the Economics faculty. Minimum grade of "C" required in all economics and statistics pre-requisite courses.
Prerequisites: (21-254 or 21-269 or 21-259 or 21-268 or 21-256) and (73-265 or 73-274 or 36-226) and 73-230 and 73-240

73-501 Tepper College Honors Thesis II

Fall and Spring
Economics majors with outstanding academic records and intellectual promise will be given the opportunity to undertake original research under the direction of individual faculty members. Research topics are selected by students and approved by faculty. Prerequisites include: Senior standing in the Economics Program and permission of the Economics faculty. Minimum grade of "C" required in all economics and statistics pre-requisite courses, and a minimum grade of "B" required in Tepper College Honors Thesis I.
Prerequisites: (21-254 or 21-269 or 21-259 or 21-268 or 21-256) and 73-230 and 73-240 and 73-500 Min. grade B and (73-374 or 73-265)

Carnegie Mellon University in Qatar

Michael Trick, Dean
Dudley Reynolds, Senior Associate Dean for Education
Undergraduate Programs Office: CMB 1101
www.qatar.cmu.edu (http://www.qatar.cmu.edu)

Carnegie Mellon University in Qatar is Carnegie Mellon's first and only undergraduate branch campus. Since 2004, it exists as part of a collaborative effort with the Qatar Foundation to bring outstanding American educational programs to the Middle East.

Degree Offerings

Carnegie Mellon University in Qatar offers four academic programs: Biological Sciences (p. 568), Business Administration (p.), Computer Science (p. 683), and Information Systems (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/informationsystems/#curriculumtextcontainer). To examine the requirements for those degrees, see their respective main campus college sections elsewhere in the Undergraduate Catalog. The purpose of this section is to describe the CMU-Q policies that are independent from those of the Pittsburgh campus and outline procedures that are common to students in all programs in Qatar.

Major Sample Schedules

Sample schedules for how CMU-Q students normally track through the academic programs can be found on the CMU-Q website as follows:

- Biological Sciences (http://www.qatar.cmu.edu/curriculum-bs/)
- Business Administration (http://www.qatar.cmu.edu/curriculum-ba/)
- Computer Science (http://www.qatar.cmu.edu/curriculum-cs/)
- Information Systems (https://www.qatar.cmu.edu/academics-research/academics/information-systems/)

Business Administration Concentrations

The concentration allows students to gain knowledge and expertise in a particular area of business practice. The concentration coursework prepares students with the knowledge and skills for their career pursuits. Completing a concentration is part of the degree requirements. Students are encouraged to declare their concentration by the end of their sophomore year.

Courses taken to meet concentration requirements are not allowed to double count toward any other BA degree requirements, including the minor requirement. The following concentrations may be completed at Carnegie Mellon University in Qatar:

- Accounting (can only be completed with a semester at the Pittsburgh campus)
- Business Analytics and Technologies
- Entrepreneurship
- Finance
- Global Economics and Business
- Islamic Business Management (forthcoming)
- Marketing Management
- Operations Management
- Strategic Management

Information Systems Concentrations

As an Information Systems major, you will select a focused concentration to provide a deep dive into a subject that interests you consisting of a minimum of three 9 unit courses and a 12 unit project or research course (39 units total). Currently approved IS Concentrations on the Qatar campus include:

- Information Security & Privacy

  The Information Security & Privacy concentration is designed to expose students to the key technical, process, and policy aspects related to information security and associated privacy concerns. The student who completes this concentration will have a solid foundation in the area and will be prepared to continue developing expertise through graduate school or their professional career.

- Data Science

  The Data Science concentration is designed to capitalize on the continuously expanding quantity of data generated through our interconnected information systems and prepares the student to understand how to store, process, retrieve, and analyze data to derive insights and improve decision making for individuals, organizations, and society. The foundation developed in this concentration prepares the graduate to assist organizations to capitalize on the data they generate as well as to support research projects either as a graduate student or within their chosen profession.

- Digitalization

  The Digitalization concentration is designed to prepare the student to understand and effectively innovate with information systems to support entrepreneurship, organizations, or society. The graduate with this concentration will often find themselves working in a larger organization or creating new organizations that capitalize on the benefits of information and information systems.

In addition to the approved concentrations, a student may choose to instead complete an approved minor or second major, or work with their advisor to develop a plan for an independent concentration.

Minors

In addition to the major degree programs, Carnegie Mellon also offers a number of minors. Minors typically consist of six courses that provide the student with substantial exposure to the core of that academic discipline. As with the major programs, the requirements of these minors are set by their respective departments on the main campus:

- Arabic Studies (advisor: Ezzohra Moufid) (https://www.cmu.edu/dietrich/lcal/academics/undergraduate/arabic.html)
- Biological Sciences (advisor: Mohamed Bouaouina) (p.)
- Business Administration (advisor: Agustin Indaco) (http://coursecatalog.web.cmu.edu/schools-colleges/tepper/undergraduatebusinessadministrationprogram/#minorstextcontainer)
- Business Analytics & Optimization (advisor Fuad Farooqi) (http://coursecatalog.web.cmu.edu/schools-colleges/tepper/undergraduatebusinessadministrationprogram/#minorstext)
- Computational Biology (advisor: Ryan Riley) (http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/undergraduatecomputatonalbiology/#minortextcontainer)
- Computer Science (advisor: Ryan Riley) (http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/undergraduatecomputerscience/#computerscienceminortextcontainer)
- Economics (advisor: Agustin Indaco) (http://coursecatalog.web.cmu.edu/schools-colleges/tepper/undergraduatebusinessadministrationprogram/#minorstextcontainer)
- Financial Management (advisor: Fuad Farooqi) (http://coursecatalog.web.cmu.edu/schools-colleges/tepper/undergraduatebusinessadministrationprogram/#minorstextcontainer)
- History (advisor: Ben Reilly) (https://scotty.qatar.cmu.edu/academic-services/minor-information/)
- Mathematical Sciences (advisor: Hasan Demirkoparan) (http://coursecatalog.web.cmu.edu/schools-colleges/melloncollegeofscience/departmentofmathematicalsciences/#minorstext)
- Media and Politics (advisor: Kira Dreher) (https://scotty.qatar.cmu.edu/academic-services/minor-information/)
- Multidisciplinary Energy Studies (advisor: Serkan Akguc) [only offered in Qatar] (https://scotty.qatar.cmu.edu/academic-services/minor-information/)
- Neuroscience (advisor: Nesrine Affara) (https://www.cmu.edu/bio/undergrad/academics/neuroscience-minor.html)
- Product Management (advisor: Fuad Farooqi) (http://coursecatalog.web.cmu.edu/schools-colleges/tepper/undergraduatebusinessadministrationprogram/#minorstextcontainer)
- Professional Writing (advisor: Thomas Mitchell) (https://www.cmu.edu/dietrich/english/academic-programs/professional-writing/pw-minor.html)
- Psychology (advisor: Jennifer Bruder) (https://www.cmu.edu/dietrich/psychology/undergraduate/prospective-students/academics/minors/)

- Sociology (advisor: Jocelyn Belanger) (http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/interdepartmentalminors/#sociologytext)
- Tech Entrepreneurship (advisor: Nui Vatanasakdakul) (https://scotty.qatar.cmu.edu/academic-services/minor-information/) [only offered in Qatar] (https://scotty.qatar.cmu.edu/academic-services/minor-information/)

Academic Standards and Actions

Academic Standards

Carnegie Mellon University in Qatar complies with common University policies unless otherwise noted. The curriculum requirements for the Biological Sciences, Business Administration, Computer Science, and Information Systems majors are set by the respective departments of the Mellon College of Science, Tepper School of Business, the School of Computer Science, and the Dietrich College of Humanities and Social Sciences and the Heinz College of Information Systems and Public Policy on the main campus. At the university level, the same academic standards, policies, and actions apply to all programs at CMU-Q as at the Pittsburgh campus.

Graduation Requirements

Residency

Candidates for a Bachelor's degree must complete a minimum of four semesters of full-time study, or equivalent part-time study, comprising at least 180 units of coursework at Carnegie Mellon.

Cumulative QPA

To be eligible to graduate, undergraduate students must complete all course requirements for their program with a cumulative Quality Point Average of at least 2.0 for all courses taken. For undergraduate students who enrolled at Carnegie Mellon as first-year students and whose first-year grades cause the cumulative QPA to fall below 2.0, this requirement is modified to be a cumulative QPA of at least 2.0 for all courses taken after the first year. Note, however, the cumulative QPA that appears on students' final transcript will be calculated based on all grades in all courses taken, including the first year. Some programs may have additional QPA requirements in order to graduate. Students are encouraged to confirm all graduation requirements with their academic advisor.

University Honors

Students maintaining a cumulative QPA of at least 3.5 after seven semesters of full-time enrollment (consecutive or otherwise) or raising their QPA to 3.5 upon completing their graduation requirements in their final semester will graduate with University Honors.

Dean's List

Students earn Dean's List recognition in a given semester by achieving one of two minimum standards. They must either 1) earn a semester QPA of 3.75 or higher (while taking at least 36 factorable units and receiving no incomplete grades), or 2) earn a semester QPA of 3.50 or higher (while taking at least 45 factorable units and receiving no incomplete grades). The CMU-Q Dean's List is calculated uniformly for all students across all majors and may differ from criteria followed for these majors on the Pittsburgh campus, where the criteria vary across colleges.

Academic Actions

Academic Actions are a part of a process designed to help students who are not meeting standards for satisfactory academic progress be successful. Students will be informed by a letter from the Area Head for their academic major if an academic action has been taken in their regard. The letter will identify individuals and resources that can help them address barriers to their success. Academic Actions may be taken for students carrying either a full-time course load (defined as 36 or more units) or a part-time course load (defined as fewer than 36 units). A student on an academic action cannot overload, study abroad, or take independent studies.

Minimum Standards

Academic Actions will be taken when students fail to meet the following standards:

- enrollment in 36 or more units (unless a drop-below full-time status has been approved by the Senior Associate Dean for Education with a note indicating that the drop will not be subject to academic action)
- a semester QPA of at least 2.0
- a cumulative QPA, or post-first-year cumulative QPA if higher, of at least 2.0, and
- making satisfactory progress towards their degree according to the standards set by their declared major.

For the purposes of calculating QPAs, all incomplete grades will be treated by their default grade until resolved. Hence, a Incomplete with a default grade of “R” would impact academic progress and QPA calculations.

Students should consult with their academic advisor or the Director of Student Academic Success to understand the standards for satisfactory progress set by their respective major. The standards are listed on CMUQ Scotty website (https://scotty.qatar.cmu.edu/academic-policies/academic-actions/).

Academic Warning

Students will be placed on **Academic Warning** status if their record at the end of a semester fails to meet the minimum standards described above. Students will return to good academic standing after one semester on Academic Warning if they then meet the minimum standards specified above.

Continued Academic Warning

If a student on Academic Warning earns a semester QPA above 2.0 but their cumulative QPA and post-first-year cumulative QPA are still below 2.0, they will be placed on **Continued Academic Warning** status. A student will also be placed on **Continued Academic Warning** status, if they earn a semester QPA above 2.0 but have not yet satisfied the conditions for satisfactory progress in their major because of course scheduling constraints. Students who are taking 36 or more units, meeting their major’s standards for satisfactory progress, and earning a semester QPA above 2.0 may continue on Continued Academic Warning until their cumulative QPA or post-first-year cumulative QPA is above 2.0.

Suspension

A student who fails to meet the minimum standards described above or those for Continued Academic Warning at the end of the Academic Warning semester will be placed on **Academic Suspension**.

Suspension is typically for a minimum of one year. While on academic suspension, students are considered to be on a mandatory "leave of absence" and are governed by College and University policies concerning leaves of absence (https://www.cmu.edu/policies/student-and-student-life/student-leave.html). Per university policy, students on suspension may not attend classes, live in university-related housing, or have on-campus employment unless they receive an exception from the Senior Associate Dean for Education.

At the end of their suspension period, the student may petition to return to CMU-Q by:

- submitting a "Petition to Return from Leave of Absence" form to the Enrollment Services Manager in Qatar;
- providing evidence in writing to the Senior Associate Dean for Education that they have fulfilled return conditions specified in the letter informing them of their suspension (if any) and have taken convincing steps to ameliorate the cause of the suspension. The student must demonstrate that they are better prepared to perform above the minimum standards for graduation than before they were suspended; and
- resolving any outstanding financial obligations.

Students will be notified by the University Registrar’s Office once their petition has been approved and their enrollment status has been updated to “eligible to enroll.” Students coming back from suspension are placed on **Final Academic Warning** status for the semester of their return. Following this semester students may either return to good academic standing or be placed on Continued Academic Warning as described above.

Drop

A student who fails to meet the minimum standards at the end of a semester on Final Academic Warning is subject to a **Drop** action. A Drop action is a permanent severance; the student is required to follow University procedures for departing from campus and may not enroll again in the future.

The typical progression of academic actions is Academic Warning, Suspension, then Drop.

Appealing an Action

In accordance with the Appeal of Academic Actions Policy (https://www.cmu.edu/student-affairs/theword/academic/appeal-of-grades-and-academic-actions.html) outlined in The Word student handbook:

"If a student believes an academic action is inconsistent with the policies of the college, a student should:

1. Submit a formal written appeal to the Associate Dean of the college responsible for the decision, with a copy to the dean, requesting review of the action including all relevant materials to substantiate the inconsistency in policy and to support their concerns.

2. The Dean of the college, or the dean's designate, will review the appeal and issue a decision and the basis for it within 30 days.

If, after carrying out the steps of either process described above, the student believes that the matter has not been adequately resolved, or if no decision has been rendered by the appropriate date, the student may appeal at the university level. To appeal at the university level, the student must present copies of all documents and a formal letter of appeal to the provost. The Provost or another designated university officer will respond in writing with a final resolution, including the basis for it, within thirty (30) days, or as soon thereafter as practical."

The Senior Associate Dean for Education is the Dean's designate at Carnegie Mellon University in Qatar responsible for reviewing academic action appeals. The appeal of an academic action to the Senior Associate Dean for Education should be made within **10 days** of receiving the initial letter with the notification of the action. Appeals at the university level to the Provost's designate must be made within **five days** of receiving the Senior Associate Dean's decision regarding the appeal.

Other Regulations Affecting Student Status

Adding a Class

Students may add classes to their schedule under the following rules:

- a full-semester course through the first 10 class days of the semester.
- a half-semester (mini) course may be added through the first 5 class days of the half-semester when the course is offered.

Dropping/Withdrawing from a Class

Students may drop or withdraw from a class as prescribed by the university's policy for doing so: https://www.cmu.edu/hub/registrar/course-changes/index.html (https://www.cmu.edu/hub/registrar/course-changes/)

Course Overloads

A maximum load for a CMU-Q student is five full-semester courses and not more than 54 units. In order to overload (i.e., take more than 54 units but no more than 63), a student must have attained a QPA of at least 3.0 in the previous semester, or have a cumulative QPA of 3.0. Approval by the student's advisor is required to overload up to the maximum (63 units). A student wishing to pursue more than 63 units must petition the Senior Associate Dean for Education to do so.

Non-Carnegie Mellon Courses

Carnegie Mellon University offers students the opportunity to take courses for credit through a cross-registration program and through the receipt of transfer credit from other accredited institutions. The Carnegie Mellon transcript will include information on such courses as follows:

- Carnegie Mellon courses and courses taken through the university's cross-registration program will have grades recorded on the transcript and be factored into the QPA.
- All other courses will be recorded on the transcript indicating where the course was taken, but no grade will be reported. Such courses will not be taken into account for academic actions, honors or QPA calculations.

Note: Suspended students may take courses elsewhere with prior approval; however, they will not receive transfer credit.

Cross Registration

Courses offered for cross-registration are those taken through an agreement with Texas A&M University at Qatar; Georgetown School of Foreign Service in Qatar; Northwestern University in Qatar; Virginia Commonwealth University in Qatar; and Weill Cornell Medical College in Qatar. Full-time students at Carnegie Mellon University in Qatar can take up to one class a semester at these schools. Cross-registration requires the completion of a cross-registration form with the appropriate signatures from the home and host institutions. Completion of the form does not guarantee a space in the requested course. The cross-registration agreement only applies during the regular academic year; normal course transfer rules apply in the summer.

Course Transfer

Students may receive credit for courses taken outside of Carnegie Mellon if they successfully petition the Senior Associate Dean for Education in advance for permission. Students must take these courses for a letter grade and instruction must be in English for non-language courses. Credit (but not the grade) will normally transfer for courses with a grade equivalent to at least a "B." The class's course description must be a close match to a Carnegie Mellon course or material covered in a range of Carnegie Mellon courses and from an accredited institution. Students may not receive credit for any courses taken on-line unless there is some safeguard to ensure that the actual student took the course (e.g., a proctored final taken under supervision at CMU-Q).

Students may not receive credit for more than five non-CMU courses during their undergraduate career as a Carnegie Mellon student. Classes taken prior to enrolling in Carnegie Mellon, during study abroad semesters, and as cross-registration with other Education City schools do not count toward the course transfer limit. All students must meet the University's residency requirement of completing at least 180 units of Carnegie Mellon coursework.

Campus Exchange and Transfer

Campus Exchange

CMU-Q and Pittsburgh students in good academic standing (not on Warning, Continued Academic Warning, Suspension, or Final Academic Warning) may study on the other campus for one semester on a space available basis and with the approval of both the home and host departments. Space constraints on both campuses may force programs to limit the number of students who can exchange in any given semester. CMU-Q students may study abroad for a second semester at another institution (not CMU Pittsburgh) if an appropriate additional study abroad opportunity arises and their academic advisor agrees. Students are expected to complete their final semester of study on their home campus unless an exception is granted by the Senior Associate Dean for Education.

Summer studies in Pittsburgh are not subject to any constraint other than not being on Suspension or Leave of Absence.

Transfer

Internally between majors at CMU-Q

Students may transfer between majors at CMU-Q on a space-available and academic performance basis. Students interested in transferring should consult with the Senior Associate Dean for Education and the Area Head of the new major. First-year students may not apply for transfer until they receive their spring mid-semester grades.

Between CMU-Q and Carnegie Mellon, Pittsburgh

Decisions about transfers to any major in Pittsburgh will be made by the Vice-Provost for Education. Transfers are only possible under specific conditions and for study beginning in a fall semester. Students interested in transferring to a major in Pittsburgh the following academic year should consult with the Senior Associate Dean for Education in Qatar as early as possible in order to understand the conditions and process for applying.

Transfers to CMU-Q from other Universities

Transfer students from other universities must apply through the Admissions Office at Carnegie Mellon University in Qatar. The Admissions Office, the Senior Associate Dean for Education, and the Area Head for the desired program will determine if there is space available and if the student's past academic performance warrants admission.

Faculty

MOHAMMAD AAZAM, Assistant Teaching Professor, Information Systems – Ph.D., Kyung Hee University; Carnegie Mellon, 2022–

IMAN ADEINAT, Associate Teaching Professor, Operations Management – Ph.D, University of New Orleans; Carnegie Mellon, 2021–

NESRINE AFFARA, AssociateTeaching Professor, Biological Sciences – Ph.D., Ohio State University; Carnegie Mellon, 2017–

SERKAN AKGUC, Associate Area Head, Business Administration; Associate Teaching Professor, Finance – Ph.D., Temple University; Carnegie Mellon, 2017–

CHADI AOUN, Area Head, Information Systems; Teaching Professor, Information Systems – Ph.D., University of New South Wales; Carnegie Mellon, 2014–

JOCELYN BELANGER, Associate Teaching Professor, Psychology, – Ph.D., University of Maryland College Park; Carnegie Mellon, 2023–

HOUDA BOUAMOR, Associate Area Head, Information Systems; Associate Teaching Professor, Information Systems – Ph.D. , Université Paris Sud; Carnegie Mellon, 2015–

MOHAMED BOUAOUINA, Associate Area Head, Biological Sciences; Associate Teaching Professor, Biological Sciences – Ph.D., Pierre and Marie Curie University; Carnegie Mellon, 2013–

JENNIFER BRUDER, Associate Dean for Research; Associate Teaching Professor, Psychology – Ph.D, University of Munich; Carnegie Mellon, 2017–

ANDRES CASTANO ZULUAGA, Assistant Teaching Professor, Economics and Analytics – Ph.D., Cornell Univeristy; Carnegie Mellon, 2023–

ANIS CHARFI, Associate Teaching Professor, Information Systems – Ph.D., Technische Universitat Darmstadt; Carnegie Mellon, 2015–

CRISTA CRITTENDEN, Instructor of Psychology – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2023–

HASAN DEMIRKOPARAN, Co-Area Head, Art and Sciences; Teaching Professor, Mathematics – Ph.D., Michigan State University; Carnegie Mellon, 2005–

GIANNI DI CARO, Teaching Professor, Computer Science – Ph.D., Université Libre de Bruxelles; Carnegie Mellon, 2016–

CRISTIAN DIMITRIU, Visiting Associate Professor, Philosphy – Ph.D, University of Toronto; Carnegie Mellon, 2022–

KIRA DREHER, Associate Dean for Diversity, Equity, Inclusion and Belonging; Assistant Teaching Professor, English – Ph.D., University of Minnesota; Carnegie Mellon, 2019–

EMILY DRILL, Associate Teaching Professor, Biological Sciences – Ph.D., University of Pittsburgh; Carnegie Mellon, 2024–

LAYAN EL HAJJ, Associate Teaching Professor, Mathematics; – Ph.D., McGill University; Carnegie Mellon, 2023–

HUSSEIN FADLALLAH, Assistant Teaching Professor, Management, – Ph.D., York University; Carnegie Mellon, 2023–

MUHAMMAD FUAD FAROOQI, Area Head, Business Administration; Teaching Professor, Finance – Ph.D., Richard Ivey School of Business; Carnegie Mellon, 2013–

SIMON FAULKNER, Assistant Teaching Professor, Chemistry – Ph.D., University College London; Carnegie Mellon, 2019–

EDUARDO FEO FLUSHING, Assistant Teaching Professor, Computer Science; – Ph.D., Università della Svizzera italiana; Carnegie Mellon, 2023–

MARIA PIA GOMEZ LAICH, Associate Teaching Professor, English – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2018–

KI-WON HAAN, Assistant Teachiing Professor, Organizational Behavior, – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2023–

SUSAN HAGAN, Associate Teaching Professor, Information Systems, Emeritus – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2024–

MAHER HAKIM, Distinguished Career Professor; – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2022–

MOHAMMAD HAMMOUD, Associate Teaching Professor, Computer Science – Ph.D., University of Pittsburgh; Carnegie Mellon, 2014–

KHALED HARRAS, Senior Associate Dean for Faculty; Teaching Professor, Computer Science – Ph.D, University of California-Santa Barbara; Carnegie Mellon, 2007–

ERIK HELIN, Lecturer, Spanish – M.A., Eastern Michigan University; Carnegie Mellon, 2006–

AGUSTIN INDACO, Assistant Teaching Professor, Economics – Ph.D., City University of New York (CUNY); Carnegie Mellon, 2019–

CHRISTOS KAPOUTSIS, Associate Teaching Professor, Computer Science – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2012–

NIRAJ KHARE, Associate Teaching Professor, Mathematics – Ph.D., The Ohio State University; Carnegie Mellon, 2014–

DIVAKARAN LIGINLAL, Teaching Professor, Information Systems – Ph.D., University of Arizona-Tucson; Carnegie Mellon, 2009–

YASSER MAJEED, Assistant Teaching Professor, Biological Sciences – Ph.D., University of Leeds; Carnegie Mellon, 2024–

SELMA LIMAM MANSAR, Teaching Professor, Information Systems, Emeritus – Ph.D., National Polytechnic Institute of Grenoble; Carnegie Mellon, 2023–

J. PATRICK MCGINNIS, Distinguished Career Professor, Business Administration – M.A., Pittsburg State University; Carnegie Mellon, 1999–

THOMAS MITCHELL, Associate Teaching Professor, English – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2013–

MANORANJAN MOHANTY, Assistant Teaching Professor, Information Systems – Ph.D., National University of Singapore; Carnegie Mellon, 2024–

EZZOHRA MOUFID, Lecturer, Modern Languages – MS, University of Roehampton; Carnegie Mellon, 2019–

NIMER MURSHID, Assistant Teaching Professor, Chemistry, – Ph.D., University of Waterloo; Carnegie Mellon, 2023–

ADVITI NAIK, Assistant Teaching Professor, Biological Sciences – Ph.D., University of Tubingen; Carnegie Mellon, 2023–

DEEPA NAIR, Assistant Teaching Professor, History – Ph.D., National University of Singapore; Carnegie Mellon, 2019–

LAMA NASIF, Associate Teaching Professor, Arabic Studies, – Ph.D., University of Texas at Austin; Carnegie Mellon, 2023–

MARION OLIVER, Teaching Professor, Mathematical Sciences, Emeritus – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2024–

TAEYONG PARK, Assistant Teaching Professor, Statistics – Ph.D., Washington University in St. Louis; Carnegie Mellon, 2017–

SILVIA PESSOA, Co-Area Head, Art and Sciences; Teaching Professor, English – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2006–

DANIEL PHELPS, Associate Teachig Professor, Information Systems, Emeritus – Ph.D., Florida State University; Carnegie Mellon, 2024–

MARY QUEEN, Visiting Associate Teaching Professor, English – Ph.D., Syracuse University; Carnegie Mellon, 2024–

BENJAMIN REILLY, Teaching Professor, History – Ph.D., University of Pittsburgh; Carnegie Mellon, 2004–

GISELLE REIS, Area Head, Computer Science; Associate Teaching Professor, Computer Science – Ph.D., Vienna University of Technology; Carnegie Mellon, 2016–

DUDLEY REYNOLDS, Senior Associate Dean, Education; Teaching Professor, English – Ph.D., Indiana University-Bloomington; Carnegie Mellon, 2007–

RYAN RILEY, Associate Area Head, Computer Science; Associate Teaching Professor, Computer Science – Ph.D., University of Purdue; Carnegie Mellon, 2017–

VELI SAFAK, Assistant Teaching Professor, Economics – Ph.D., Georgetown University; Carnegie Mellon, 2019–

REYA SALIBA, Instruction and Outreach Librarian; – Ph.D., Lancaster University; Carnegie Mellon, 2023–

VARUN SHARMA , Assistant Teaching Professor, Marketing – Ph.D., Bocconi University; Carnegie Mellon, 2019–

JEFFREY SQUIRES, Assistant Teaching Professor, English – Ph.D., University of Minnesota Twin-Cities; Carnegie Mellon, 2019–

MICHAEL TRICK, Dean of Carnegie Mellon University in Qatar and Harry B. and James H. Higgins Professor of Operations Research – Ph.D., Georgia Institute of Technology; Carnegie Mellon, 2017–

TATIANA USOVA, Director, Library – MLIS, Simmons University; Carnegie Mellon, 2022–

SAVANID VATANASAKDUL, Associate Teaching Professor, Information Systems – Ph.D., University of South Wales; Carnegie Mellon, 2017–

ANTHONY WESTON, Associate Teaching Professor, Mathematics; – Ph.D., Kent State University; Carnegie Mellon, 2022–

ZELEALEM YILMA, Associate Teaching Professor, Mathematics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2014–

IHAB YOUNIS, Area Head, Biological Sciences; Associate Teaching Professor, Biological Sciences – Ph.D., Ohio State University; Carnegie Mellon, 2015–

MOHAMED ZAYED, Associate Teaching Professor, Physics – D.Sc., ETH Zurich; Carnegie Mellon, 2017–

Interdisciplinary Programs

Carnegie Mellon University offers several degree programs and courses of study which are coordinated by multiple colleges, reflecting the interdisciplinary nature of the university. These are detailed below.

Intercollege Majors

- BXA Intercollege Degree Programs
  - Bachelor of Humanities and Arts Program
  - Bachelor of Engineering Studies and Arts Program
  - Bachelor of Science and Arts Program
  - Bachelor of Computer Science and Arts Program
- B.S. in Computational Finance
- B.S. in Music and Technology
- B.S. in Neuroscience
- B.S. in Psychology and Biological Sciences
- Major in General Studies

INTERCOLLEGE ADDITIONAL MAJOR

- Environmental & Sustainability Studies
- BXA Intercollege Degree Programs
  - Engineering and Arts

Intercollege Minors

- Minor in Computational Finance
- Minor in Environmental & Sustainability Studies
- Minor in Game Design (IDeATe)
- Minor in Health Care Policy and Management
- Minor in Immersive Technologies in Arts & Culture

BXA Intercollege Degree Programs

The BXA Intercollege Degree Programs enable students the freedom to individualize their educational experience by promoting integration, balance and innovation. BXA offers the following programs:

- Bachelor of Humanities and Arts
- Bachelor of Engineering Studies and Arts
- Bachelor of Computer Science and Arts
- Bachelor of Science and Arts
- Engineering and Arts Additional Major

For detailed information on the BXA Intercollege Degree Programs, go to BXA Intercollege Degree Programs (p. 894).

Bachelor of Science in Computational Finance

The Mellon College of Science, the Heinz College of Public Policy and Management and the Tepper School of Business jointly offer a degree uniquely designed to meet the quantitative needs of the finance industry. Modeled after the highly successful Carnegie Mellon Master of Science in Computational Finance, this degree allows students to develop a deep knowledge of mathematics, probability, statistics, and the applications of these disciplines to finance. Students who complete this degree may directly enter the finance industry, enter other industries where applied mathematics training is appropriate, or pursue advanced degrees in economics, finance or the mathematical sciences. Students entering the work force upon completion of this degree may wish to later complement their undergraduate degree with a Master's degree in Business Administration or another professional degree. Students who might eventually pursue doctoral degrees in economics, finance, statistics or mathematics should seek advising on how to use their electives in order to prepare for graduate work in their chosen disciplines.

The Bachelor of Science in Computational Finance is an Intercollege Program. Students may pursue Computational Finance as their primary major with either the Mellon College of Science (MCS) or the Tepper School of Business (Tepper) as their home college. The coursework required for the major is essentially the same in each case, with a few minor exceptions outlined below. The general education requirements for the degree depend on the student's home college.

Students who pursue Computational Finance as an additional major will remain in the college of their primary major. Additional majors must complete the Major Requirements outlined below, but not the General Education Requirements outlined for MCS and Tepper students. Additional majors will complete the general education requirements for their home college.

Admission to the major in Computational Finance is by application. Applications are accepted each fall and spring semester. The application deadline has traditionally been just after the mid-semester break. Applicants must have taken (or be currently taking) at the time of application: 21-127 Concepts of Mathematics (or 21-128), 21-241 Matrices and Linear Transformations (or 21-242), 21-270 Introduction to Mathematical Finance. Students from any college or program at Carnegie Mellon are welcome to apply to enroll in the major. Additional information about computational finance and the Undergraduate Computational Finance Program at Carnegie Mellon can be found on the BSCF Program website.

Several majors are prohibited in combination with the Computational Finance major (either as Primary/Additional majors or as Dual Degrees) due to excessive overlap with the Computational Finance curriculum. These include the Business Administration major, the major in Mathematical Sciences (including any of the various concentrations), and the major in Economics and Mathematical Sciences.

Major Requirements

The major in Computational Finance is built around a core sequence of courses in mathematical finance. This core is supported by courses providing foundational mathematical skills and augmented with coursework in the related areas of Statistics, Computer Science, and Economics. Additionally the major provides training in the "soft skills" required for work in a corporate environment. The major also requires the completion of several depth electives, allowing students to tailor their education to their particular interests and needs.

The major requirements are the same for additional majors as they are for majors whose home college is MCS. There are a few slight differences for students whose home college is Tepper. These differences are described in the sections for Depth Electives and Professional Development below.

Foundations

21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
21-127	Concepts of Mathematics	12
21-241	Matrices and Linear Transformations	11
21-259	Calculus in Three Dimensions	10
21-260	Differential Equations	9
21-369	Numerical Methods	12
70-122	Introduction to Accounting	9

Mathematical Finance

21-270	Introduction to Mathematical Finance	9
21-370	Discrete Time Finance	9
21-420	Continuous-Time Finance	9
46-977	MSCF Studies in Financial Engineering	6

Statistics

21-325	Probability	9
36-226	Introduction to Statistical Inference	9
36-401	Modern Regression	9

Programming

15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
15-122	Principles of Imperative Computation	12

Economics

73-102	Principles of Microeconomics	9
or 73-104	Principles of Microeconomics Accelerated	

73-103	Principles of Macroeconomics	9
73-240	Intermediate Macroeconomics	9

Professional Development

94-700	Organizational Design & Implementation	6
95-717	Writing for Information Systems Management	6
95-718	Professional Speaking	6

Note: Majors in the Tepper School of Business take 70-311 Organizational Behavior as part of the Functional Business Core curriculum. This course will satisfy the 94-700 Organizational Design & Implementation requirement for these students. Majors in the Tepper School of Business also take 70-340 Business Communications as part of the Functional Business Core curriculum. This course will satisfy the 95-717 Writing for Information Systems Management requirement for these students.

Depth Electives

Depth electives give students an opportunity to tailor their coursework to their particular interests. Students completing the major will take three depth electives (the minimum requirement is 24 units - the equivalent of two 9 unit courses and one 6 unit course).

Note: Tepper students are required to select 70-391 Finance as one of their depth electives.

Depth electives are intended to develop a student's background in an area that is applicable to the finance industry. Courses in finance or programming generally qualify as depth electives. Mathematics, Statistics, or Economics courses in areas applicable to finance also qualify. Computational Finance majors may have the opportunity to take MSCF courses (as described below) and these may also be counted as depth electives.

There is no definitive list of approved depth electives. The courses listed below have been taken as depth electives in recent years, but other courses could be approved upon request

10-301	Introduction to Machine Learning	12
10-601	Introduction to Machine Learning (Master's)	12
10-605	Machine Learning with Large Datasets	12
15-150	Principles of Functional Programming	12
15-210	Parallel and Sequential Data Structures and Algorithms	12
15-213	Introduction to Computer Systems	12
15-351	Algorithms and Advanced Data Structures	12
15-451	Algorithm Design and Analysis	12
21-393	Operations Research II	9
21-355	Principles of Real Analysis I	9
21-378	Mathematics of Fixed Income Markets	9
36-402	Advanced Methods for Data Analysis	9
36-410	Introduction to Probability Modeling	9
36-462	Special Topics: Statistical Machine Learning	9
36-463	Special Topics: Multilevel and Hierarchical Models	9
36-464	Special Topics: Psychometrics: A Statistical Modeling Approach	9
70-391	Finance	9
70-492	Investment Analysis	9
70-495	Corporate Finance	9
70-497	Derivative Securities	9

MSCF Courses

Computational Finance majors are required to take 46-977 MSCF Studies in Financial Engineering. They may also have the opportunity to take up to four more MSCF courses. Permission to enroll in these courses requires (1) approval from the BSCF program, (2) approval of the course instructor, and (3) space available in the course. The MSCF curriculum (https://www.cmu.edu/mscf/academics/curriculum/) with course descriptions is described on the MSCF website (https://www.cmu.edu/mscf/).

Some MSCF courses cover material in the undergraduate curriculum and thus are not generally suitable. Other courses require background that is difficult to obtain as an undergraduate. Students interested in taking MSCF courses are encouraged to discuss their interest with their BSCF advisor as early as possible.

General Education Requirements

Students completing Computational Finance as an additional major will complete the general education requirements from their home department and college. Students completing Computational Finance as their primary major in either MCS or Tepper will complete a modified version of the general education requirements from their home college. These requirements are outlined below.

General Education Requirements for MCS Students

Students in the Mellon College of Science completing the Computational Finance major as their primary major must complete the requirements below in addition to the major requirements.

99-101	Core@CMU	3
76-101	Interpretation and Argument	9
or 76-102	Advanced First Year Writing: Special Topics	
or 76-106	Writing about Literature, Art and Culture	
or 76-107	Writing about Data	
or 76-108	Writing about Public Problems	

Technical Breadth Requirement

A student must take at least 18 units of MCS technical breadth courses total, one from “Life Sciences” and one from “Physical Sciences”. AP/IB/Cambridge credit may not be used to fulfill these requirements. CMU placement exam credit can be used to fill these requirements. Transfer courses from an accredited college/university will be considered for these technical breadth requirements. To support educational exploration, courses taken to satisfy BSCF major requirements may not be used to satisfy the general education requirements. Courses that have been approved for each category can be found below.

A. Life Sciences

(Some courses have prerequisites that can be satisfied by AP, IB, Cambridge A Level Exams. Please check the prerequisites requirements as necessary.)

LIFE SCIENCES COURSES		
02-250	Introduction to Computational Biology	12
02-261	Quantitative Cell and Molecular Biology Laboratory	Var.
03-116	Phage Genomics Research * Offered only in Doha	6
03-117	Frontiers, Analysis, and Discovery in Biological Sciences	6
03-121	Modern Biology	9
03-151	Honors Modern Biology	10
03-124	Modern Biology Laboratory	9
03-125	Evolution	9
03-132	Basic Science to Modern Medicine	9
03-133	Neurobiology of Disease	9
03-135	Structure and Function of the Human Body	9
03-161	Molecules to Mind	9
03-231	Honors Biochemistry	9
03-232	Biochemistry I	9
42-101	Introduction to Biomedical Engineering	12
42-202	Physiology	9
85-219	Foundations of Brain and Behavior	9

B. Physical Sciences

(Some courses have prerequisites that can be satisfied by AP, IB, Cambridge A Level Exams. Please check the prerequisites requirements as necessary.)

PHYSICAL SCIENCES COURSES		
09-105	Introduction to Modern Chemistry I	10
09-106	Modern Chemistry II	10
09-107	Honors Chemistry: Fundamentals, Concepts and Applications	10
09-111	Nanolegos: Chemical Building Blocks	9
09-214	Physical Chemistry	9
09-217	Organic Chemistry I	9
09-219	Modern Organic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-225	Climate Change: Chemistry, Physics and Planetary Science	9

09-348	Inorganic Chemistry	10
33-121	Physics I for Science Students	12
33-122	Physics II for Biological Sciences & Chemistry Students	9
33-141	Physics I for Engineering Students	12
33-142	Physics II for Engineering and Physics Students	12
33-151	Matter and Interactions I	12
33-152	Matter and Interactions II	12
33-211	Physics III: Modern Essentials	10
33-224	Stars, Galaxies and the Universe	9
33-225	Quantum Physics and Structure of Matter	9

Non-Technical Elective: Cognition, Choice, and Behavior

One of the following:

80-100	Introduction to Philosophy	9
80-130	Introduction to Ethics	9
80-150	Nature of Reason	9
80-180	Nature of Language: An Introduction to Linguistics	9
80-208	Critical Thinking	9
80-220	Philosophy of Science	9
80-221	Philosophy of Social Science	9
80-270	Problems of Mind and Body: Meaning and Doing	9
80-271	Mind and Body: The Objective and the Subjective	9
80-312	Mathematical Revolutions	9
80-330	Ethical Theory	9
85-102	Introduction to Psychology	9
85-211	Cognitive Psychology	9
85-221	Principles of Child Development	9
85-241	Social Psychology	9
85-251	Personality	9
85-261	Psychopathology	9
88-120	Reason, Passion and Cognition	9

Though any of these courses will satisfy the Cognition, Choice, and Behavior requirement, students are strongly encouraged to consider taking one of the ethics courses: 80-130 or 80-330.

Non-Technical Elective: Cultural Analysis

One of the following:

57-173	Survey of Western Music History	9
57-209	The Beatles	9
70-342	Managing Across Cultures	9
76-232	Introduction to Black Literature	9
76-239	Introduction to Film Studies	9
76-241	Introduction to Gender Studies	9
79-104	Global Histories	9
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-205	20th Century Europe	9
79-225	West African History in Film	9
79-229	The Origins of the Palestinian-Israeli Conflict, 1880-1948	9
79-230	The Arab-Israeli Conflict and Peace Process Through 1948 to Present	9
79-240	Development of American Culture	9
79-239	History of the American Working Class	9
79-242	African American History: Reconstruction to the Present	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-265	Russian History: Game of Thrones	9
79-266	Russian History and Revolutionary Socialism	9
79-281	Introduction to Religion	9
79-345	Roots of Rock & Roll	9
79-350	Early Christianity	9
80-100	Introduction to Philosophy	9
80-250	Ancient Philosophy	9
80-251	Modern Philosophy	9
80-253	Continental Philosophy	9
80-254	Analytic Philosophy	9
80-255	Pragmatism: Making Ideas Work	9
80-261	Experience, Reason, and Truth	9
80-276	Philosophy of Religion	9
82-xxx	Any courses from Modern Languages	

Non-Technical Electives: Two Additional Courses

In addition to the Cognition, Choice and Behavior and the Cultural Analysis requirements, majors in MCS must take two more courses (at least 18 units) from any of the departments in DC, CFA or Tepper, subject to the list of deletions (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/deletions.html) and additions (https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/additions.html) maintained by MCS.

Additional Notes

BSCF majors in MCS may use AP credits to satisfy nontechnical general education requirements. However, students cannot count more than 18 units from AP/IB/Cambridge exam credit towards these requirements. Transfer courses from an accredited college/university will be considered for these nontechnical breadth requirements. To support educational exploration, courses taken to satisfy BSCF major requirements may not be used to satisfy the general education requirements.

General Education Requirements for Tepper Students

Students in the Tepper School of Business completing the Computational Finance major as their primary major must complete the requirements below in addition to the major requirements.

Tepper Functional Business Core

Computational Finance majors whose home college is Tepper will complete a modified version of the Tepper Functional Business Core curriculum.

The Functional Business Core of the Undergraduate Business Administration Program includes 70-122 Introduction to Accounting, which is required by all Computational Finance majors. It also includes 70-391 Finance, which Tepper students majoring in Computational Finance must select as of one their Depth Electives. In addition, Tepper students pursuing the B.S. in Computational Finance must complete six other courses from the Functional Business Core.

These courses are:

70-106	Business Science	9
70-311	Organizational Behavior	9
70-332	Business, Society and Ethics	9
70-371	Operations Management	9
70-381	Marketing I	9
70-401	Management Game	12

Liberal Arts & Sciences Breadth Requirements

Candidates for the B.S. in Computational Finance must complete the Liberal Arts & Sciences Breadth Requirements as described in the catalog entry for the B.S. Degree in Business Administration.

Sample Curricula

MCS Sample Curriculum

What follows is the detailed curriculum for the degree Bachelor of Science in Computational Finance in the Mellon College of Science. This is an example of how an MCS student might meet the requirements of the Computational Finance major. It is not expected that every student will follow this sequence. In particular, well prepared students should consider taking 21-270 Introduction to Mathematical Finance during their Freshman Spring semester. Students intending to do so are encouraged to take 21-127

Concepts of Mathematics or 21-241 Matrices and Linear Transformations during their Freshman Fall semester.

Freshman	
Fall	**Spring**
15-110 Principles of Computing	15-112 Fundamentals of Programming and Computer Science
21-120 Differential and Integral Calculus	21-122 Integration and Approximation
76-101 Interpretation and Argument	70-122 Introduction to Accounting
99-101 Core@CMU	xx-xxx Science Requirement
xx-xxx Science Requirement	xx-xxx Elective

Sophomore	
Fall	**Spring**
21-241 Matrices and Linear Transformations	21-270 Introduction to Mathematical Finance
21-259 Calculus in Three Dimensions	21-127 Concepts of Mathematics
21-260 Differential Equations	21-369 Numerical Methods
73-102 Principles of Microeconomics	73-103 Principles of Macroeconomics
xx-xxx Humanities, Social Sciences, or Fine Arts Elective	xx-xxx Elective

Junior	
Fall	**Spring**
21-325 Probability	21-420 Continuous-Time Finance
21-370 Discrete Time Finance	36-226 Introduction to Statistical Inference
73-240 Intermediate Macroeconomics	xx-xxx Humanities, Social Sciences, or Fine Arts Elective
15-122 Principles of Imperative Computation	xx-xxx Humanities, Social Sciences, or Fine Arts Elective
xx-xxx Elective	xx-xxx Depth Elective

Senior	
Fall	**Spring**
46-977 MSCF Studies in Financial Engineering	95-717 Writing for Information Systems Management
94-700 Organizational Design & Implementation	95-718 Professional Speaking
36-401 Modern Regression	xx-xxx Depth Elective
xx-xxx Depth Elective	xx-xxx Humanities, Social Sciences, or Fine Arts Elective
xx-xxx Elective	xx-xxx Elective
xx-xxx Elective	xx-xxx Elective

Tepper Sample Curriculum

What follows is the detailed curriculum for the degree Bachelor of Science in Computational Finance in the Tepper School of Business. This is an example of how a Tepper student might meet the requirements of the Computational Finance major. It is not expected that every student will follow this sequence. In particular, well prepared students should consider taking 21-270 Introduction to Mathematical Finance during their Freshman Spring semester. Students intending to do so are encouraged to take 21-127 Concepts of Mathematics or 21-241 Matrices and Linear Transformations during their Freshman Fall semester.

Freshman	
Fall	**Spring**
15-110 Principles of Computing	15-112 Fundamentals of Programming and Computer Science
21-120 Differential and Integral Calculus	21-122 Integration and Approximation
73-102 Principles of Microeconomics	21-241 Matrices and Linear Transformations
70-106 Business Science	73-103 Principles of Macroeconomics
76-101 Interpretation and Argument	xx-xxx Breadth Course
99-101 Core@CMU	xx-xxx Breadth Course

Sophomore	
Fall	**Spring**
21-127 Concepts of Mathematics	21-270 Introduction to Mathematical Finance
21-259 Calculus in Three Dimensions	21-325 Probability
21-260 Differential Equations	70-311 Organizational Behavior
70-122 Introduction to Accounting	70-381 Marketing I
xx-xxx Elective	73-240 Intermediate Macroeconomics

Junior	
Fall	**Spring**
21-369 Numerical Methods	21-420 Continuous-Time Finance
21-370 Discrete Time Finance	36-226 Introduction to Statistical Inference
70-391 Finance	70-371 Operations Management
15-122 Principles of Imperative Computation	xx-xxx Breadth Course
xx-xxx Breadth Course	xx-xxx Breadth Course

Senior	
Fall	**Spring**
36-401 Modern Regression	95-717 Writing for Information Systems Management
46-977 MSCF Studies in Financial Engineering	95-718 Professional Speaking
70-332 Business, Society and Ethics	xx-xxx Depth Elective
70-401 Management Game	xx-xxx Breadth Course
xx-xxx Depth Elective	xx-xxx Breadth Course
	xx-xxx Elective

Minor in Computational Finance

Unlike the major in Computational Finance, there is no application process for the minor in Computational Finance, however in order to declare the minor in Computational Finance, a student must satisfy one of the following sets of requirements:

1. Completion of 21-270 Introduction to Mathematical Finance with a grade of A and an overall QPA of at least 3.20; OR
2. Completion of 21-270 Introduction to Mathematical Finance and 21-370 Discrete Time Finance with an average grade of B and an overall QPA of at least 3.00; OR
3. Completion of 21-270 Introduction to Mathematical Finance and 21-378 Mathematics of Fixed Income Markets with an average grade of B and an overall QPA of at least 3.00.

When a student has met the necessary requirements, he or she may declare the minor by contacting the Associate Director of the Undergraduate Computational Finance program.

> ***Note:*** *For students who have a grade of P in either 21-270 or 21-378 from the Spring 2020 semester (and only that semester) these requirements have been altered slightly. The grade of P will not be counted toward the averages in conditions 2 or 3. This effectively makes the requirements*
>
> *1. Completion of* 21-270 Introduction to Mathematical Finance *with a grade of A and an overall QPA of at least 3.20; OR*
>
> *2. Completion of* 21-270 Introduction to Mathematical Finance *and* 21-370 Discrete Time Finance *with an average grade of B and an overall QPA of at least 3.00; OR*
>
> *2a. Completion of* 21-270 Introduction to Mathematical Finance *with a grade of P in Spring 2020, and completion of* 21-370 Discrete Time Finance *with a minimum grade of B and an overall QPA of at least 3.00; OR*
>
> *3. Completion of* 21-270 Introduction to Mathematical Finance *and* 21-378 Mathematics of Fixed Income Markets *with an average grade of B and an overall QPA of at least 3.00; OR*
>
> *3a. Completion of* 21-270 Introduction to Mathematical Finance *with a grade of P in Spring 2020, and completion of* 21-378 Mathematics of Fixed Income Markets *with a minimum grade of B and an overall QPA of at least 3.00.*

21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
21-259	Calculus in Three Dimensions	9-12
or 21-256	Multivariate Analysis	
or 21-268	Multidimensional Calculus	
or 21-269	Vector Analysis	
21-260	Differential Equations	9-10
or 21-261	Introduction to Ordinary Differential Equations	
21-270	Introduction to Mathematical Finance	9
21-370	Discrete Time Finance *	9
21-420	Continuous-Time Finance **	9

To avoid excessive double counting, Computational Finance minors may not count 21-270 Introduction to Mathematical Finance, 21-370 Discrete Time Finance or 21-420 Continuous-Time Finance toward any other requirement.

* The prerequisites for 21-370 are 21-270 and either 21-256 or 21-259 , and the co-requisite is 70-207 , 21-325 , 36-225 or . Note that 70-207 is not accepted as a prerequisite for 21-420.

** The prerequisites for 21-420 are 21-260 , 21-370 and one of the following three calculus based probability courses: 21-325 , 36-225 or . Note that 70-207 is not a sufficient preparation in probability. Also note that 21-122 is a prerequisite for 21-260 and that 21-127 is recommended for 21-241 .

Students minoring in Computational Finance are strongly encouraged to take one or two economics course, e.g., 73-102, 73-103, 73-230 , or 73-240 .

Environmental & Sustainability Studies

Program in Environmental and Sustainability Studies

```
Abigail Owen, Program Director & Program Faculty, Minor and
 Additional Major in Environmental & Sustainability Studies
Erin Dean, Program Faculty, Minor and Additional Major in
 Environmental & Sustainability Studies
Ryan Sullivan, Program Faculty, Minor and Additional Major in
 Environmental & Sustainability Studies
Neil Donahue, Director, Steinbrenner Institute for Environmental
 Education and Research
Kara Scully, Program Assistant
```

https://www.cmu.edu/steinbrenner/undergraduate-program/index.html (https://www.cmu.edu/steinbrenner/undergraduate-program/)

Maggie Braun, Associate Dean for Undergraduate Affairs, Mellon College of Science
Sharon Carver, Associate Dean for Educational Affairs, Marianna Brown Dietrich College of Humanities & Social Sciences

The Steinbrenner Institute for Environmental Education & Research, the Dietrich College of Humanities & Social Sciences, and the Mellon College of Science have joined together to establish the interdisciplinary Program in Environmental & Sustainability Studies, offering a Minor or an Additional Major.

The Minor and Additional Major in Environmental & Sustainability Studies are designed to be accessible for any undergraduate student at Carnegie Mellon University, regardless of primary major and college, and without extensive prerequisite barriers. Building from core coursework, students can tailor their elective coursework, with intensive guidance from program advisors, to integrate appropriate electives from a wide range of possible courses to develop a coherent course of study with appropriate depth and breadth.

Additional Major in Environmental and Sustainability Studies

The additional major is designed to allow students from any college at CMU to build on the depth of their primary major and address the breadth of intrinsically interdisciplinary issues associated with the environment and sustainability.

There is no application process for the program in Environmental and Sustainability Studies, however a student must declare the Minor or Additional Major by contacting the Advisor or Program Director of the Environmental and Sustainability Studies program. Core course 66-236 “Introduction to Environmental Ideas” (9 Units) is offered in both the spring and fall semesters and features a smaller, intimate class size. Students are encouraged to declare the Minor or Additional Major as early as possible, so they can receive priority in course registration, though all are welcome to take this course.

The Additional Major combines natural science, social science, and humanistic studies. These are co-equal. How Earth functions as a system is fundamental: key topics include climate, ecosystems, environmental chemistry (the behavior of molecules within the environment) and energy systems. Human interactions with the environment, and so the details of how cultural, political, and social systems function, are critical to understand, with an emphasis on sustainability and the environment. Issues of ethics, equity, and justice, situated in historical context, are vital to a full and complex understanding with a goal of equitable and appropriate solutions to environmental crises.

The three pillars are:

1. Earth and Environmental Science. Majors should understand how the Earth works as a system, with more advanced understanding of selected scientific topics associated with Environment and Sustainability.
2. Political Economy. Majors should understand the consequences and options of economics and policy at the local, regional, and global level.
3. Humanities for Environment and Sustainability. Additional Majors should understand cultural, social, historical, ethical, and political aspects of environment and sustainability, including environmental, climate, and social justice.

Students who pursue the Additional Major will be able to:

- Apply humanistic, social, and scientific perspectives for problems of environment and sustainability
- Distinguish among scientific methods for evaluating problems of environment and sustainability
- Explain how aspects of history, culture, ethics, language, and arts relate to environment and sustainability, including goals for environmental justice and global climate justice.
- Assess sources of data about environment and sustainability
- Formulate a research question for interdisciplinary studies of environment and sustainability. Identify discipline-specific methods for exploring or answering the questions posed and use the chosen methods to gather and analyze evidence

Double-Counting

Maximum 3 courses, regardless of Units, can be double-counted for the Additional Major from any other Minor, Major, or Master’s program. This maximum does not apply to General Education courses.

General Education courses

Courses taken to fulfill a General Education requirement for the student’s college (the college of the student's primary major) are not calculated as “double-counting” for the Additional Major in Environmental and Sustainability Studies.

AP credit

AP courses are not counted towards requirements for the Additional Major in Environmental and Sustainability Studies.

Study abroad

Courses taken abroad may count towards Electives for the Additional Major, if accepted for transfer credit by the relevant CMU department and approved by the Program Director.

Requirements for the Additional Major in Environmental & Sustainability Studies

- `Minimum 102 Units Total for students with primary majors in CFA, Dietrich, Tepper`
- `Minimum 105 Units Total for students with primary majors in MCS, Engineering, SCS`

Core Courses: Complete 27 Units for students with Primary majors in CFA, Dietrich, Tepper; Complete 30 Units for Students with Primary Majors in MCS, Engineering, SCS		Units
24-291	Environmental Systems on a Changing Planet Cross-listed as 09-291	9
24-381	Environmental Systems on a Changing Planet Cross-listed as 09-381. This 12-unit course is required for students with primary majors in MCS, Engineering, or SCS.	12
66-236	Introduction to Environmental Ideas	9
66-506	Senior Capstone	9

Earth and Environmental Science - Complete any one (minimum 9 Units)		Units
03-128	Biology for Life Special Topics Section S, "Tropical Ecology" (9 units) offered at CMU Study Abroad Program in Costa Rica; Without prerequisite	9
03-140	Ecology and Environmental Science Without prerequisite	9
33-115	Physics for Future Presidents Without prerequisite	9
09-225	Climate Change: Chemistry, Physics and Planetary Science	9
09-510	Chemistry and Sustainability	9
09-524	Environmental Chemistry	9
09-529	Introduction to Sustainable Energy Science	9
09-538	Exposure and Risk Assessment for Environmental Pollutants	9
33-226	Physics of Energy	9

Global Course - Complete any one (3 Units)		Units
99-384	Technology, Humanity, and Social Justice: Health Each semester, a new 3-Unit course 99-xxx is offered on Global themes, in partnership with University of Pittsburgh's Global Studies Center.	3

Statistics & Data Science - Complete 9 Units		Units
36-200	Reasoning with Data This requirement can only be fulfilled with a course taken in the Department of Statistics & Data Science at CMU. AP Statistics does not fulfill this requirement. Students with AP credit can place into a higher-level course offered by the same Department, for example 36-202 or 36-290.	9

Political Economy - Complete any one (Minimum 9 Units)		Units
19-101	Introduction to Engineering and Public Policy Without prerequisite	12
79-300	Controversial Topics in the History of American Public Policy Without prerequisite	9
84-110	The Economics of Politics, Policy, and Technology Without prerequisite	9
84-226	International Relations Without prerequisite	9
84-325	Contemporary American Foreign Policy Without prerequisite	9
88-344	Systems Analysis: Environmental Policy Without prerequisite	9
73-332	Political Economy	9
73-408	Law and Economics	9
73-427	Sustainability, Energy, and Environmental Economics	9
84-310	Policy in a Global Economy 1: International Trade and Trade Policy	9
88-221	Markets, Democracy, and Public Policy	9
88-366	Behavioral Economics of Poverty and Development	9

Electives for Environmental & Sustainability Studies - Complete 45 Units

For the Additional Major, select and complete at least 45 Units of eligible electives in consultation with the Program Advisor and/or Program Director. At least 36 out of 45 Units of Electives for the Additional Major should be "External electives" completed outside of the college where the student's primary major is housed; this is to encourage students to pursue interdisciplinary breadth. The remaining 9 Units of Electives for the Additional Major are "Free electives" from any college, including the student's own primary college.

Example

A student with a primary Major in Art (College of Fine Arts) could complete up to 9 Units of Electives for the Additional Major within the College of Fine Arts. This means up to 9 Units of Electives could be taken in Music, Design, Architecture, Drama, or Art; the remaining 36 Units of Electives must come from outside CFA: from Dietrich, Engineering, Business, or Science.

Electives are vetted by the program director from the CMU course catalog and listed each term based on the following criteria. Additional courses meeting these criteria can be approved by the program director.

Additional courses from these categories always count as electives:

- Any additional courses listed in the above category "Earth and Environmental Science" can be counted as electives.
- Any additional courses listed in the above category "Political Economy" can be counted as electives.
- Any additional courses listed in the above category "Global Course" can be counted as electives.

Any further electives should:

- Broaden the reach of the student's interdisciplinary explorations in environment and sustainability
- Thematically, courses should either add to depth from above-listed categories: "Earth and Environmental Science"; "Environmental Humanities"; "Three Unit Global Course"; and/or "Political Economy";
- Or, electives should increase the student's interdisciplinary grasp of topics related to environment and sustainability, with particular emphasis on topics related to environmental justice and/or global climate justice.

Minor in Environmental and Sustainability Studies

There is no application process for the program in Environmental and Sustainability Studies, however a student must declare the Minor or Additional Major by contacting the Advisor or Program Director of the Environmental and Sustainability Studies program. Core course 66-236 "Introduction to Environmental Ideas" (9 Units) is offered in both the spring and fall semesters and features a smaller, intimate class size. Students are encouraged to declare the Minor or Additional Major as early as possible, so they can receive priority in course registration, though all are welcome to take this course.

Students who pursue the minor will be able to:

- Identify humanistic, social, and scientific perspectives for problems of environment and sustainability
- Distinguish among scientific methods for evaluating problems of environment and sustainability
- Connect how aspects of history, culture, ethics, language, and arts relate to environment and sustainability, including goals for environmental justice and global climate justice
- Discuss sources of data about environment and sustainability

Double-Counting

Maximum 2 courses, regardless of Units, can be double-counted for the Minor from any other Minor, Major, or Master's program. This maximum does not apply to General Education courses.

General Education courses

Courses taken to fulfill a General Education requirement for the student's college (the college of the student's primary major) are not calculated as "double-counting" for the Minor in Environmental and Sustainability Studies.

AP credit

AP courses are not counted towards requirements for the Minor in Environmental and Sustainability Studies.

Study abroad

Courses taken abroad may count towards Electives for the Minor, if accepted for transfer credit by the relevant CMU department and approved by the Program Director.

Requirements for the Minor in Environmental & Sustainability Studies

- `Minimum 66 Units Total for students with primary majors in CFA, Dietrich, Tepper`
- `Minimum 69 Units Total for students with primary majors in MCS, Engineering, SCS`

Core Courses: Complete 18 Units for students with Primary majors in CFA, Dietrich, Tepper; Complete 21 Units for Students with Primary Majors in MCS, Engineering, SCS		Units
24-291	Environmental Systems on a Changing Planet Cross-listed as 09-291	9
24-381	Environmental Systems on a Changing Planet Cross-listed as 09-381. This 12-unit course is required for students with primary majors in MCS, Engineering, or SCS.	12
66-236	Introduction to Environmental Ideas	9

Global Course - Complete any one (3 Units)		Units
99-384	Technology, Humanity, and Social Justice: Health	3

Statistics & Data Science - Complete 9 Units		Units
36-200	Reasoning with Data This requirement can only be fulfilled with a course taken in the Department of Statistics & Data Science at CMU. AP Statistics does not fulfill this requirement. Students with AP credit can place into a higher-level course offered by the same Department, for example 36-202 or 36-290.	9

Electives for Environmental & Sustainability Studies - Complete 36 Units

For the Minor, select and complete at least 36 Units of eligible electives in consultation with the Program Advisor and/or Program Director. At least 27 out of 36 Units of Electives for the Minor should be "External electives" completed outside of the college where the student's primary major is housed; this is to encourage students to pursue interdisciplinary breadth. The remaining 9 Units of Electives for the Minor are "Free electives" from any college, including the student's own primary college.

Example

A student with a primary Major in Art (College of Fine Arts) could complete up to 9 Units of Electives for the Minor within the College of Fine Arts. This means up to 9 Units of Electives could be taken in Music, Design, Architecture, Drama, or Art; the remaining 27 Units of Electives for the Minor must come from outside CFA: from Dietrich, Engineering, Business, or Science.

Electives are vetted by the program director from the CMU course catalog and listed each term based on the following criteria. Additional courses meeting these criteria can be approved by the program director.

Additional courses from these categories always count as electives:

- Any additional courses listed in the above category "Earth and Environmental Science" (see Additional Major requirements) can be counted as electives.
- Any additional courses listed in the above category "Political Economy" (see Additional Major requirements) can be counted as electives.
- Any additional courses listed in the above category "Global Course" can be counted as electives.

Any further electives should:

- Broaden the reach of the student's interdisciplinary explorations in environment and sustainability
- Thematically, courses should either add to depth from above-listed categories: "Earth and Environmental Science"; "Environmental Humanities"; "Three Unit Global Course"; and/or "Political Economy";
- Or, electives should increase the student's interdisciplinary grasp of topics related to environment and sustainability, with particular emphasis on topics related to environmental justice and/or global climate justice.

Game Design Minor – IDeATe

The *Game Design* minor is offered by the Entertainment Technology Center (https://www.etc.cmu.edu/learn/about-the-etc/) as part of the Integrative Design, Arts and Technology (https://ideate.cmu.edu/) (IDeATe) network. IDeATe offers students the opportunity to become immersed in a collaborative community of faculty and peers who share expertise, experience, and passions at the intersection of arts and technology. Students will engage in active "learning by doing" in shared labs and maker spaces. The program addresses current and emerging real-world challenges that require disciplinary expertise coupled with multidisciplinary perspectives and collaborative integrative approaches.

The IDeATe undergraduate curriculum consists of ten areas, all of which can also be taken as minors. The themes of these areas integrate knowledge in technology and arts: Game Design, Animation & Special Effects, Media Design, Design for Learning, Sonic Arts, Innovation and Entrepreneurship, Intelligent Environments, Physical Computing, Soft Technologies, and Immersive Technologies in Arts & Culture. For more information about the IDeATe network, please visit Undergraduate Options (p.).

Game design is an art, a craft, and a science. Students in the IDeATe *Game Design* minor will gain mastery in all three aspects through game design, development, and assessment. You will learn about the rich histories, theory, and practice of game creation taught by faculty experts, and have opportunities to collaborate across the many disciplines needed to make successful game experiences. Through coursework you will be able to realize your own unique aesthetics and voice by reflecting on your own game play and by thoughtfully critiquing the games of others. Through the minor students will be able to build a strong game design portfolio, deepen cultural sensitivities as a game designers, and expand their creative practice. In particular, you will gain skills and competencies in the following areas of game design:

- Game systems and mechanics design
- Interactive narrative and character development
- Visual and audio asset creation
- Game programming
- Interface design and user testing
- Collaboration and the iterative design process

Curriculum

One Computing Course - Minimum of 9 Units

		Units
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
60-212	Intermediate Studio: Creative Coding	12

One IDeATe Portal Course - Minimum of 9 Units

		Units
16-223	IDeATe Portal: Creative Kinetic Systems	10
18-090	Twisted Signals: Multimedia Processing for the Arts	10
53-322	IDeATe: Little Games/Big Stories: Indie Roleplaying Game Studio Recommended Portal Course for this area (Spring only)	9
60-125	IDeATe: Introduction to 3D Animation Pipeline	12

60-223	IDeATe Portal: Introduction to Physical Computing	10
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis Recommended Portal Course for this area (Sec. B)	10
82-250	Digital Realities: Introducing Immersive Technologies for Arts and Culture	9
99-361	IDeATe Portal Sec A: Learning about Learning; Sec B: Intelligent Environments	9

IDeATe Game Design Courses - Minimum of 27 Units

		Units
05-418	Design Educational Games	12
05-499	Special Topics in HCI For sections related to Game Design	12
15-466	Computer Game Programming	12
53-230	Programming for Game Designers	12
53-320	IDeATe Special Topics in Animation: Character Modeling	6
53-321	IDeATe Special Topics in Animation: Bipedal Rigging for Animation Production	6
53-323	IDEATE Storytelling Through Effects Animation	6
53-353	Understanding Game Engines	9
53-371/76-368	Role Playing Games Writing Workshop	12
53-373	Dynamic Motion and Game Experience	12
53-451	Research Issues in Game Development: Designing for XR	12
53-471	Game Design, Prototyping and Production	15
53-472	Advanced Game Studio	12
60-333	IDeATe: Animation Rigging	10
60-419	Advanced ETB: Experimental Game Studio: Digital Playgrounds	10

Additional courses as available. Please refer to the IDeATe website for the list of Game Design courses for the currnent and upcoming semesters.

Double-Counting

Students may double-count up to two of their *Game Design* minor courses toward requirements for other majors or minors.

Major in General Studies

The Bachelor of Arts and Bachelor of Science in General Studies provide students a pathway through a broad educational foundation while adhering to the strong standards of a CMU degree.

The General Studies major covers both intercollegiate breadth and discipline-specific knowledge. The intercollegiate educational requirements expose students to a variety of intellectual and cultural approaches and provide serviceable knowledge on a range of topics. In addition to this liberal arts style foundation, students are required to declare and complete an academic minor. This concentrated study equips students with in-depth knowledge of a given professional field. Students are challenged to move beyond base assumptions and to demonstrate higher order creativity, analysis, and application. Additionally, the academic minor sends a concrete signal to future employers to indicate areas of interest and experience: “BA/BS in General Studies” also requires a “Minor in X”. Near the end of their degree, General Studies students synthesize their educational pursuits. They are required to register for a 3+ unit Independent Study/Capstone to create a culminating project/paper. This course requires a supervising faculty advisor and is presented at Meeting of the Minds or an equivalent pre-approved public forum.

Eligibility and approval

A student cannot independently pursue this degree. Any student expressing interest in transferring to the General Studies major must discuss their motivation and alternative options with their academic advisor, receive approval from their college’s Assistant/Associate Dean, and then be approved by the General Studies Academic Advisory Committee. Students must work with their Assistant/Associate Dean to first exhaust the following options:

- maintaining their current degree path,
- changing majors in one’s home college, or
- transferring to another college at CMU.

In order to be considered for the General Studies major program, a student must fulfill all of the criteria:

1. A student must have successfully completed at least 180 units, 75% of which were completed at CMU.
2. A student must have passed the University’s general education requirements: “First-Year Writing” and “Computing at CMU.” See table below for full listing of courses that can satisfy these requirements.
3. A student must demonstrate the ability to be successful in their intended minor. Students must be on track to complete at least 50% of the minor’s coursework at the point of application.
4. A student must create both a Success Plan and Curricular Plan with their advisor. This plan must include monthly meetings with their academic advisor, outline a plan for continual satisfactory academic progress, and be approved by their Assistant/Associate Dean.

If all the above criteria are met, each student’s case is brought to the General Studies Academic Advisory Committee and must receive a majority vote to advance.

Degree Structure and Graduation Requirements

In accordance with Carnegie Mellon’s standards and degree norms, all candidates must complete the following requirements in order to graduate with a General Studies major:

1. Apply and be approved by the General Studies Academic Advisory Committee as a General Studies Major.
2. Adhere to and make progress toward the agreed upon Success and Curricular plans.
3. Declare and complete an academic minor in your home college or gain approval and complete a minor in another college. (Transfer credit acceptance will be determined by the equivalent CMU department). Additional minors beyond the General Studies degree with a minor in x will not be considered unless the secondary minor’s units are in addition to all of the General Studies degree requirements.
4. Graduation requirements are broadly defined as follows, and outlined in the following “Curriculum” section:
    a. Earn a minimum of 360 units.
    b. Students may count up to 40 non-factorable units with a maximum of 9 total non-factorable units of StuCo, ROTC, and P/E.
    c. Students must have a minimum of 45 units in upper level courses, as defined by the course’s home department (generally 300 level or above).
    d. Pass/fail courses may not be used for the primary major or minor requirements (for courses that are otherwise letter graded). Pass/fail courses may not be used for the general education requirements of the degree.
    e. Earn a QPA of at least 2.0 for all courses taken (For undergraduate students who enrolled at Carnegie Mellon as freshmen and whose freshman grades cause the cumulative QPA to fall below 2.00, this requirement is modified to be a cumulative QPA of at least 2.00 for all courses taken after the freshman year.)

Curriculum

Minimum units required for B.A./B.S. in General Studies 360

Seminar requirement

99-430	General Studies Capstone Course	**3-12, variable**

First-year writing REQUIREMENT

Complete a total of 9 units from the following courses.

76-101	Interpretation and Argument	9
76-102	Advanced First Year Writing: Special Topics	9
76-106	Writing about Literature, Art and Culture	4.5
76-107	Writing about Data	4.5
76-108	Writing about Public Problems	4.5

general studies REQUIREMENTs

99-101	Computing @ CMU	**3**
Breadth coursework	Minimum of 18 units in each of three different CMU school/colleges covering at least five departments (this can include the school/ department that the student is currently enrolled in).	**54 units**

The courses used to satisfy the breadth requirement must be in addition to the minimum total of 45 units in upper level courses required for the major.

MIDDLE STATES REQUIREMENTS

General Studies students should have a well-rounded education that fulfills Middle States Accreditation requirements, demonstrating learning in each of seven categories. Students will work with their advisor and associate dean (or equivalent) to guarantee that each category is fulfilled, recognizing what they have done while exploring other degrees across departments and colleges. Courses counting for their major and/or minor can be used to fulfill these requirements.

Communication (oral, written, and visual)	**Variable units**
Information literacy	**Variable units**
Critical thinking	**Variable units**
Cultural and social understanding	**Variable units**
Personal development	**Variable units**
Quantitative reasoning	**Variable units**
Scientific reasoning	**Variable units**

Minor in Immersive Technologies in Arts & Culture

Students in the Immersive Technologies in Arts & Culture (https://ideate.cmu.edu/undergraduate-programs/immersive-technologies-in-arts-culture/) minor will be hybrid technologists, media-makers, and storytellers who can create mediated experiences at the intersection of technology, design, and the humanities. They will be equipped with the social consciousness, global awareness, and cross-cultural skills needed to forge positive new paths for immersive media going into the future.

Students in the minor will learn to construct and deconstruct immersive and augmented experiences with respect to the cultural, socio-emotional, and embodied aspects of human experience. They will develop the technical know-how and creative production skills to collaboratively author original narratives and prototype spatially mediated experiences. In the making of augmented and immersive media, students will explore the narrative possibilities and technical affordances of the genre while attending to the aesthetic considerations, humanistic concerns, and design conventions defining this emerging mode of cultural production.

One IDEATE Portal Course (minimum of 9 units):

82-250	Digital Realities: Introducing Immersive Technologies for Arts and Culture	9

One Intercultural Focus Course (minimum of 9 units):

82-280	Billingual & Bicultural Experiences in the US	9
82-282	Interpreting Global Texts & Cultures	9
82-283	Language Diversity & Cultural Identity	9

One Computing Course (minimum of 9 units):

15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
60-212	Intermediate Studio: Creative Coding	12

IDeATe Immersive Technologies Courses (minimum of 27 units)*:

15-365	Experimental Animation	12
or 60-422	Advanced ETB: Experimental Animation	
15-463	Computational Photography	12
53-353	Understanding Game Engines	9
53-373	Dynamic Motion and Game Experience	12
53-376	360 Story and Sound	12
53-451	Research Issues in Game Development: Designing for XR	12
53-558	Reality Computing Studio	12
54-397	Sound Design For Interactive Environments	9
54-399	Decoding Media	9
60-413	Advanced ETB: Real-Time Animation	10
82-284	Multicultural Pittsburgh: VR Storytelling	9
82-287	Multicultural Immersion - Relating Your World in Virtual Reality	6

**Additional courses are available. Please check* IDeATe Courses *(*https://ideate.cmu.edu/courses/current-courses.html*) for the options for the current and upcoming semester.*

Double-counting: Students may double-count up to two of their IDeATe minor courses for other requirements.

Minor in Health Care Policy and Management

Sponsored by:
Heinz College of Information Systems and Public Policy
Dietrich College of Humanities and Social Sciences
Mellon College of Science

Faculty Advisors:
Jason D'Antonio, Mellon College of Science
James F. Jordan, H. John Heinz III College

The face of health care is changing. The practice of medicine is being fundamentally altered by the forces of change in public policy, health care organizations and in the industry as a whole. The role of individual professionals in this industry is changing as rapidly as the industry itself. Traditional career paths have disappeared overnight to be replaced by new opportunities that require new skills. New organizations are placing new demands on their professional and medical staffs. The criteria of efficiency and financial stability are entering the domains of diagnosis and treatment.

This minor is designed to provide students considering a career in the health professions with an understanding of how these changes are likely to affect their careers. Students will become familiar with the critical policy and management issues and will begin to learn to operate effectively in the emerging health care environment. The curriculum combines economic, organizational, managerial, historical and psychological perspectives on these issues to provide a foundation for a deepened understanding of the changing structure of health care organizations and policy.

Required Courses for HCPM Minor

A total of 54 units are required to complete this minor. Entry into the minor requires completion of 73-102 Principles of Microeconomics or the equivalent by approval.

Required Courses

Complete a total of 21 units from the following:		
79-330	Medicine and Society: Health, Healers, and Hospitals	9
90-436	Health Systems	6
90-472	Health Policy	6

Elective Courses

Complete a minimum of 24 units from these two sections:

Heinz College Courses		
94-409	Healthcare Information Systems	12
73-328	Health Economics	12
90-832	Health Law	6
90-433	Population Health	6

90-834	Health Care Geographical Information Systems	12
Other courses as approved		

Humanities and Social Sciences Courses (9 units each)		
80-245	Medical Ethics	9
76-494	Healthcare Communications	9
88-365	Behavioral Economics and Public Policy	9
42-444	Medical Devices	9
Other courses as approved		

Please note that some of these courses have prerequisites that will not count toward the completion of the requirements for this minor.

Elective Focus Areas

Focus areas are suggested groupings of electives based on student interest. Students *do not* need to take all electives within one focus area; they are free to choose their 18-unit elective minimum from any combination of focus areas.

Health Management/Administration Focus		Units
90-832	Health Law	6
80-245	Medical Ethics	9
76-494	Healthcare Communications	9

Health Policy Focus		Units
73-328	Health Economics	12
90-832	Health Law	6
90-433	Population Health	6
88-365/90-882	Behavioral Economics and Public Policy	9
Other courses as approved		

Health Analytics & IT Focus		Units
94-409	Healthcare Information Systems	12
90-834	Health Care Geographical Information Systems	12
42-444	Medical Devices	9
Other courses as approved		

B.S. in Psychology & Biological Sciences

Veronica Hinman, *Department Head, Biological Sciences*

Susanne Ferber, *Department Head, Psychology*

This major is intended to reflect the interdisciplinary nature of current research in the fields of biology and psychology, as well as the national trend in some professions to seek individuals broadly trained in both the social and natural sciences.

Note: Students entering from the Dietrich College of Humanities and Social Sciences will earn a Bachelor of Science in Psychology and Biological Sciences. Students in the Mellon College of Science will earn a Bachelor of Science in Biological Sciences and Psychology.

Depending on a student's home college (DC or MCS), General Education (GenEd) requirements will be different. GenEd requirements for DC (p. 353) and MCS (p. 560) are found on their respective Catalog pages.

Degree Requirements:

Biological Sciences		Units
03-151	Honors Modern Biology	10
or 03-121	Modern Biology	
03-201	Undergraduate Colloquium for Sophomores *Only required for MCS Students	2
03-220	Genetics	9
or 03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	
03-231	Honors Biochemistry	9
03-320	Cell Biology	9
03-343	Experimental Techniques in Molecular Biology	12
03-411	Topics in Research	1
03-412	Topics in Research	1
03-xxx	General Biology Elective [1]	9
03-3xx	Advanced Biology Elective [1]	18
Total Biology units		**80**

[1] Please see description and requirements for electives under the B.S. in Biological Sciences section of this Catalog.

Mathematics, Statistics, Physics and Computer Science		Units
21-120	Differential and Integral Calculus	10
21-124	Calculus II for Biologists and Chemists	10
or 21-122	Integration and Approximation	
36-200	Reasoning with Data	9
36-309	Experimental Design for Behavioral & Social Sciences	9
or 85-309	Statistical Concepts and Methods for Behavioral and Social Science	
33-121	Physics I for Science Students [3]	12
or 33-141	Physics I for Engineering Students	
15-110	Principles of Computing	10-12
or 15-112	Fundamentals of Programming and Computer Science	
99-101	Core@CMU	3
Total Science units		**63-65**

[3] MCS students must also complete 33-122 Physics II for Biological Sciences & Chemistry Students.

Chemistry		Units
09-105	Introduction to Modern Chemistry I	10
09-106	Modern Chemistry II	10
09-217	Organic Chemistry I	9
09-218	Organic Chemistry II	9
09-207	Techniques in Quantitative Analysis	9
09-208	Techniques for Organic Synthesis and Analysis	9
Total Chemistry units		**56**

Psychology Courses		Units
85-102	Introduction to Psychology	9
85-219	Foundations of Brain and Behavior	9
85-xxx	Survey Psychology Courses *	18
85-310	Research Methods in Cognitive Psychology	9
or 85-300	Introduction to Research Methods	
or 85-314	Cognitive Neuroscience Research Methods	
or 85-320	Research Methods in Developmental Psychology	
or 85-330	Analytic Research Methods	
or 85-340	Research Methods in Social Psychology	
85-3xx	Advanced Psychology Electives	18
Total Psychology units		**63**

* Excluding 85-104 Psychopathology

Additional Advanced Elective 9 units

(Choose one of the following courses)		
85-3xx	Advanced Psychology Elective	9
or		
03-3xx	Advanced Biology Elective	9

Additional Laboratory or Research Methods 9-12 units

(Choose one of the following courses)		
03-344	Experimental Biochemistry	12
03-345	Experimental Cell and Developmental Biology	12
03-346	Experimental Neuroscience	12
85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9
85-320	Research Methods in Developmental Psychology	9
85-330	Analytic Research Methods	9
85-340	Research Methods in Social Psychology	9

Elective Units	Units
Free Electives	33-36
MCS Nontechnical Breadth or DC General Education requirements	36-48
Total Elective units	**69-84**

Minimum number of units required for degree: 360

Bachelor of Science in Music and Technology

The Bachelor of Science in Music and Technology is offered jointly by the School of Music, the School of Computer Science, and the College of Engineering.

This program consists of a set of courses that span both music and technology, as well as a capstone composition/design/performance project. Courses in all three areas of study are stipulated in the music and technology undergraduate curriculum and provide for students coming from any of the three areas. In other words, regardless of a student's entry point — an interest in computer science, electrical engineering, or music — the coursework prescribed will allow the student to gain the requisite knowledge and experience in all three areas. Students will work closely with advisors and will be guided in both course selection and capstone projects.

Curriculum

Minimum units required for B.S. in Music and Technology 380

General Requirements — 85 units

Seminar

57-570	Music and Technology Seminar (8 semesters for a total of 8 units)	1

University

99-101	Core@CMU	3
76-101	Interpretation and Argument	9
xx-xxx	Global, Cultural, and Diverse Perspectives Course	9

Humanities

xx-xxx	Cognition, Choice and Behavior course	9
xx-xxx	English, History, Modern Languages, Philosophy, or Psychology course	9

Mathematics

21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10

Science

33-114	Physics of Musical Sound	9
33-141	Physics I for Engineering Students	12

Electives — 33 or 37 units

Music Core — 81 units

57-152	Harmony I	9
57-153	Harmony II	9
57-408	Form and Analysis	6
57-151	Counterpoint in Theory and Application	6
57-258	20th-21st Century Techniques	6
57-257	Orchestration I	6
57-189	Introduction to Repertoire and Listening for Musicians	3
57-190	Repertoire and Listening for Musicians I	3
57-289	Repertoire and Listening for Musicians II	3
57-290	Repertoire and Listening for Musicians III	3
57-181	Solfege I	3
57-182	Solfege II	3
57-183	Solfege III	3
57-184	Solfege IV	3
57-161	Eurhythmics I	3
57-162	Eurhythmics II	3
57-173	Survey of Western Music History	9

Music and Technology Core — 121 units

15-112	Fundamentals of Programming and Computer Science	12
15-122	Principles of Imperative Computation	12
15-322	Introduction to Computer Music	9
18-100	Introduction to Electrical and Computer Engineering	12
18-202	Mathematical Foundations of Electrical Engineering	12
18-290	Signals and Systems	12
57-101	Introduction to Music Technology	6
57-347	Electronic and Computer Music	6
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-438	Multitrack Recording	9
57-571	Music and Technology Project	12
57-572	Music and Technology Project	12

Concentration

Students complete either the Music Concentration or the Technical Concentration:

Music Concentration — 60 units

57-5xx	Studio (4 semesters)	36
57-4xx	Major Ensemble (4 semesters)	24

Technical Concentration — 58 or 56 units

21-127	Concepts of Mathematics	12
15/18-213	Introduction to Computer Systems	12

AND EITHER:

18-220	Electronic Devices and Analog Circuits	12
18-240	Structure and Design of Digital Systems	12
15-2xx/18-3xx or above	Electives in ECE or CS	12

OR:

15-210	Parallel and Sequential Data Structures and Algorithms	12
15-323	Computer Music Systems and Information Processing	9
15-2xx/18-3xx or above	Electives in ECE or CS	12

Bachelor of Science in Neuroscience

Veronica Hinman, *Department Head, Biological Sciences*

Michael Tarr, *Department Head, Psychology*

www.cmu.edu/ni (https://www.cmu.edu/ni/)

Neuroscience is an interdisciplinary field in which scientists from many backgrounds apply the tools of biology, cognitive science, psychology, chemistry, mathematics, statistics, computer science, and engineering to develop a comprehensive understanding of brain function at the level of molecules, neurons, brain circuits, cognitive brain modules, and behavior. Research in neuroscience across these disciplines has grown substantially in the past two decades, and a solid understanding of the physiological basis of many aspects of brain function both in health and disease has come along with this growth in research. Along with this comes an increasing need for students to begin careers in neuroscience and to be prepared to work on the problems in neuroscience and to bring new answers to the public and to patients. In order to be successful in developing new treatments and answering outstanding questions in the field, neuroscientists need to be conversant in many different levels of inquiry from neurobiology to cognitive neuroscience to computational neuroscience.

The Dietrich College of Humanities & Social Sciences and the Mellon College of Science have joined forces to establish an exciting interdisciplinary program leading to a Bachelor of Science in Neuroscience. The goal of this degree program is to provide an intensive interdisciplinary education to enable outstanding students to become leaders in identifying and solving tomorrow's Neuroscience problems using a variety of methods. The program's interdisciplinary curriculum is designed for students to gain a fundamental understanding of brain function on many different levels and to begin to specialize within the broad field of Neuroscience. Students in Mellon College of Science or Dietrich College may have a primary major in Neuroscience in any of the three concentrations. Students from other colleges may have a second major in Neuroscience in any of the three concentrations, subject to double-counting restrictions.

A degree in neuroscience provides excellent preparation for medical school or other graduate programs in the health professions. These students are aided by the Carnegie Mellon Health Professions Program (HPP), an advisory and resource service for all Carnegie Mellon students who are considering careers in the health care field. (See the HPP (p.) section in this catalog or www.cmu.edu/hpp (http://www.cmu.edu/hpp/) for more information.)

Students wishing to pursue the Neuroscience major through Dietrich College should contact Dr. Lori Holt (loriholt@cmu.edu). Students wishing to pursue the Neuroscience major through the Mellon College of Science should contact the Biological Sciences Undergraduate Programs Office (bio-ungrad@andrew.cmu.edu). Students wishing to pursue an additional major in either the Neurobiology or Computational Neuroscience concentrations should contact the Biological Sciences Undergraduate Programs Office (bio-ungrad@andrew.cmu.edu). Students wishing to pursue an additional major in the Cognitive Neuroscience concentration should contact Dr. Lori Holt (loriholt@cmu.edu).

Students who pursue this major will:

- Gain a broad understanding of Neuroscience at many different levels of analysis, including: cellular biology of the brain, brain systems, cognitive brain function, and computational brain modeling
- Gain an understanding of the sciences underlying Neuroscience, including: Biology, Chemistry, Computer Science, Cognition and Psychology, and other emerging areas
- Develop a comprehensive understanding of brain function in health and disease
- Be familiar with neuroanatomy & neurophysiology and their implications for nervous system function
- Be prepared for advanced study in neurobiology, cognitive neuroscience, and/or neural computation
- Be able to collaborate with Neuroscientists across a wide range of systems and levels of analysis
- Prepare for careers in Neuroscience related companies, Neuroscience research, and/or medicine
- Be prepared for specialization within subfields of Neuroscience given their concentration selection

Requirements for a B.S. in Neuroscience

All students must complete the following:

1. General Science Requirements (see section A)
2. Core Neuroscience Courses (see section B)
3. Requirements for one concentration (see sections C, D, or E)*
4. 18 additional relevant course units in their home concentration or other neuroscience areas (some examples listed in sections C, D, E, & F). At least 9 of these units must be at the 300-level or above.
5. Their home college's General Education requirements
6. Free elective units to come to a total of 360 total course units

* **Double-counting restrictions and additional majors & minors**

- Students may not major in two concentrations.
- Students using Neuroscience as an additional major or who have an additional major or minor to Neuroscience may only double-count at most 3 courses between this an their other major or minor (this restriction does not apply to prerequisites, General Education Requirements, or the General Science Requirements – section A).
- Other majors and minors may have more stringent double-counting restrictions, please consult with your neuroscience advisors and with the advising staff for the relevant host department for the other majors/minors.

A. General Science Requirements

		Units
21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	
03-121	Modern Biology	9
or 03-151	Honors Modern Biology	
03-201	Undergraduate Colloquium for Sophomores *Only required for MCS Students	1
03-220	Genetics	9
or 03-221	Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis	
09-105	Introduction to Modern Chemistry I	10
09-106	Modern Chemistry II	10
09-207	Techniques in Quantitative Analysis [1]	9-12
or 09-221	Laboratory I: Introduction to Chemical Analysis	
or 03-124	Modern Biology Laboratory	
09-217	Organic Chemistry I [1]	9
or 33-122	Physics II for Biological Sciences & Chemistry Students	
33-121	Physics I for Science Students	12
15-110	Principles of Computing [2]	10-12
or 15-112	Fundamentals of Programming and Computer Science	
36-200	Reasoning with Data [2]	9
or 36-218	Probability Theory for Computer Scientists	
or 36-219	Probability Theory and Random Processes	
or 36-225	Introduction to Probability Theory	
99-101	Core@CMU	3
		111-116

1 Neurobiology concentration students are required to complete 09-217 & 09-207 or 09-221.

2 Computational Neuroscience concentration students are required to complete 21-122, 15-112, & 36-218 or 36-219

B. Core Neuroscience Courses

		Units
85-219	Foundations of Brain and Behavior [3]	9
or 03-161	Molecules to Mind	
85-211	Cognitive Psychology	9
or 85-213	Human Information Processing and Artificial Intelligence	
03-362	Cellular Neuroscience	9
03-363	Systems Neuroscience	9
15-386	Neural Computation [4]	9
or 85-419	Introduction to Parallel Distributed Processing	
or 02-319/03-360	Genomics and Epigenetics of the Brain	
or 86-375	Computational Perception	
or 85-435	Biologically Intelligent Exploration	
		45

3 Cognitive Neuroscience concentration students are required to complete 85-219.

4 Computational Neuroscience concentration students are required to complete 15-386.

C. Neurobiology Concentration

Didactic Core: Students must complete all of the following*		Units
03-231	Honors Biochemistry	9
03-320	Cell Biology	9
		18

* Neurobiology concentration students must complete 09-217 & 09-207 or 09-221 in their General Science Requirements (section A, above)

Required laboratory, data analysis, & methodological courses		Units
03-343	Experimental Techniques in Molecular Biology	12
03-346	Experimental Neuroscience	12
or 03-345	Experimental Cell and Developmental Biology	
		24

Electives in Neurobiology (minimum of 18 additional units, at least 9 units at 300-level or above)**		Units
03-133	Neurobiology of Disease	9
02-250	Introduction to Computational Biology	12
03-350	Developmental Biology	9
03-365	Neural Correlates of Learning and Memory	9
03-366	Neuropharmacology: Drugs, Brain and Behavior	9
03-439	Introduction to Biophysics	10

03-442	Molecular Biology	9
09-218	Organic Chemistry II	9
09-208	Techniques for Organic Synthesis and Analysis	9
or 09-222	Laboratory II: Organic Synthesis and Analysis	
42-202	Physiology	9
42-203	Biomedical Engineering Laboratory NOTE: VERY Limited Seating Available for 42-203	9

** At least 9 of these units must be 300-level or above

D. Cognitive Neuroscience Concentration

Didactic Core. Students must complete all of the following		Units
85-102	Introduction to Psychology	9
36-309	Experimental Design for Behavioral & Social Sciences	9
		18

Required laboratory, data analysis, & methodological courses		Units
85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9
		18

Electives in Cognitive Neuroscience (minimum of 27 additional hours)**		Units
85-221	Principles of Child Development	9
85-241	Social Psychology	9
85-261	Psychopathology	9
85-356	Expertise: The cognitive (neuro)science of mastering almost any skill	9
85-370	Perception	9
85-406	Autism: Psychological and Neuroscience Perspectives	9
85-408	Visual Cognition	9
85-412	Cognitive Modeling	9
85-414	Cognitive Neuropsychology	9
85-419	Introduction to Parallel Distributed Processing *	9
85-424	Hemispheric Specialization: Why, How and What?	9
85-426	Learning in Humans and Machines	9
85-429	Cognitive Brain Imaging	9
85-442	Health Psychology	9
85-501	Readings in Developmental psychology	9

* If not used as a core course
** At least 18 of these units must be 300-level or above

E. Computational Neuroscience Concentration

Strong candidates for the Computational Neuroscience Concentration will have earned a B average in 21-127, 21-241, 15-112, and 15-122. We strongly recommend meeting with your advisor to discuss interest in this major and for help planning appropriate schedules to support student success.

Didactic Core. Students must complete all of the following*		Units
21-127	Concepts of Mathematics	12
15-122	Principles of Imperative Computation	12
or 15-150	Principles of Functional Programming	
21-241	Matrices and Linear Transformations	10
or 21-240	Matrix Algebra with Applications	
		34

* Computational Neuroscience concentration students must complete 21-122, 15-112, and 36-218 or 36-219 in their General Science Requirements (section A, above) and 15-386 in their Core Neuroscience Courses (section B, above). Students must complete a minimum of 60 units in this concentration. Students should select their required laboratory and elective courses to complete a minimum of 31 units (Four 9 unit courses or a lesser number of 9 and 12 unit courses could be combined to complete this requirement).

Required laboratory, data analysis, and methodological courses (18-24 total units)		Units
42/86-631	Neural Data Analysis	12
42-632	Neural Signal Processing	12
15-494	Cognitive Robotics: The Future of Robot Toys	12
15-883	Computational Models of Neural Systems	12
85-419	Introduction to Parallel Distributed Processing	9
85-435	Biologically Intelligent Exploration	9

Electives in Computational Neuroscience (minimum of 9 units)		Units
03-360/02-319	Genomics and Epigenetics of the Brain	9
02-512	Computational Methods for Biological Modeling and Simulation	9
10-301	Introduction to Machine Learning	12
or 10-315	Introduction to Machine Learning (SCS Majors)	
or 10-601	Introduction to Machine Learning (Master's)	
15-387	Computational Perception	9
15-451	Algorithm Design and Analysis	12
15-453	Formal Languages, Automata, and Computability	9
15-494	Cognitive Robotics: The Future of Robot Toys	12
15-883	Computational Models of Neural Systems	12
16-299	Introduction to Feedback Control Systems	12
16-311	Introduction to Robotics	12
21-228	Discrete Mathematics	9
or 15-251	Great Ideas in Theoretical Computer Science	
21-259	Calculus in Three Dimensions	10
21-341	Linear Algebra	9
36-226	Introduction to Statistical Inference	9
36-350	Statistical Computing	9
36-401	Modern Regression	9
36-462	Special Topics: Statistical Machine Learning	9
42/86-631	Neural Data Analysis	12
42-632	Neural Signal Processing	12
42-688	Introduction to Neural Engineering	12

F. Additional Neuroscience Electives

Students are required to take a minimum of 18 additional relevant course units beyond those required for the concentration. These electives can be additional coursework from their home concentration or other neuroscience areas. Some examples are listed in sections C, D, & E above as well as in the list below. At least 9 of these additional 18 units must be at the 300-level or above.

NOTE: this list is not restrictive. Concentration advisors can approve additional elective courses that contribute to the student's neuroscience education, subject to additional approval by the major steering committee.

Examples of Additional Electives relevant to major*		
33-122	Physics II for Biological Sciences & Chemistry Students unless used for Science Core (section A)	9
76-385	Introduction to Discourse Analysis	9
80-210	Logic and Proofs	9
80-211	Logic and Mathematical Inquiry	9
80-220	Philosophy of Science	9
80-254	Analytic Philosophy	9
80-270	Problems of Mind and Body: Meaning and Doing	9
80-280	Linguistic Analysis	9

* Up to 9 units of applicable undergraduate research course work (e.g. 03-445 or 85-507/85-508) can count as a neuroscience elective (not towards a concentration). A maximum of 27 additional units can be counted as a free electives.

Free Electives (depending on concentration & college)	**51-61**
TOTAL hours to degree	**360**

BXA Intercollege Degree Programs

M. Stephanie Murray, Senior Associate Dean of Interdisciplinary Initiatives
Location: Hall of the Arts 211
www.cmu.edu/interdisciplinary (http://www.cmu.edu/interdisciplinary/)

Mission Statement

The BXA Intercollege Degree Programs are designed for students who want to turn talent and passion into viable professions for the future through a challenging academic curriculum. BXA students pursue their goals with the help of multifaceted advising, innovative pedagogical strategies and a focus on the impact arts have on technology and vice versa.

The goal of the Bachelor of Computer Science and Arts (BCSA), the Bachelor of Engineering Studies and Arts (BESA), the Bachelor of Humanities and Arts (BHA), the Bachelor of Science and Arts (BSA) and the additional major in Engineering and Arts (EA), housed under the BXA Intercollege Degree Programs, is to allow a select group of students who demonstrate interest and accomplishment in the fine arts and computer science, engineering, humanities, social sciences or natural sciences to explore beyond the traditional academic major, or integrate more than one field of study across disciplines. These programs foster the creativity of students who explore innovative approaches to the academic environments of two colleges. By merging the components in the arts and computer science, engineering, natural sciences or humanities into an interdisciplinary/multidisciplinary study, a unique, complex product is born. BXA students produce new information, challenging questions and innovative theory. BXA students are models of independence, motivation and well-rounded scholarship as humanists, scientists and artists at the same time.

In the context of the Carnegie Mellon University environment, the BXA Intercollege Degree Programs hold a special role. BXA provides access to five strong colleges that offer specialized training with expert faculty and researchers. The BXA Programs challenge students to utilize those resources as they explore and develop their own approach to interdisciplinary studies in the fine arts and computer science, engineering, humanities and social sciences, or the natural and mathematical sciences.

BXA students balance courses in their CFA concentration with courses in their academic concentration, as well as BXA-specific courses. These BXA-specific courses give students the opportunity to integrate their areas of concentration by focusing on interdisciplinary approaches and arts-based research techniques. The curricula in the concentration areas provide students with a solid disciplinary foundation upon which they can draw for interdisciplinary projects.

A BXA intercollege degree prepares students for graduate study and careers in an enormous variety of fields, including traditional graduate training in the arts as well as academic areas, positions in arts and education non-profits such as museums and foundations, and technical positions with media and technology companies.

Program Objectives

The skills developed by BXA students span the creative, the technical, the academic and the practical. The objective of the BXA Intercollege Degree Programs is to prepare graduates for careers in which they will draw on their creative and academic skills to create, educate, communicate and innovate across disciplines.

Students who complete the BXA curriculum will graduate with the following skills:

- Foundational knowledge and technical expertise in the CFA concentration area and the DC/ENG/MCS/SCS concentration area
- Ability to describe the connections between these concentrations and how the student integrates them
- Ability to communicate ideas textually, visually and orally
- Knowledge of how the concentration disciplines intersect with history, society and culture from local and global perspectives
- Ability to use cognitive, behavioral and ethical dimensions within the concentration disciplines to make decisions on individual and social levels
- Experience in engaging in art research to produce new knowledge both within the CFA concentration and the DC/ENG/MCS/SCS concentration
- Experience in designing, researching and completing a large-scale, object-based project that integrates both areas of concentration

Bachelor of Computer Science and Arts Degree Program

The Bachelor of Computer Science and Arts (BCSA) intercollege degree program combines the strengths of the College of Fine Arts (CFA) and the School of Computer Science (SCS). This degree provides an ideal technical, critical and conceptual foundation for students interested in pursuing fields that comprehensively meld technology and the arts, such as game design, computer animation, computer music, recording technologies, interactive stagecraft, robotic art and other emerging media. Students choose their arts concentration from the following schools in CFA: Architecture, Art, Design, Drama or Music. Students choose their computer science concentration established by the School of Computer Science.

The BCSA curriculum has three main components: general education requirements, fine arts concentration requirements and computer science concentration requirements. Each student's course of study is structured so they can complete this rigorous program in four years.

Students receive extensive advising support. The academic advisors in the BXA Intercollege Degree Programs are the primary advisors and liaisons between CFA and SCS. Each student has two additional academic advisors: an advisor in the admitting school of CFA to guide their focus in the arts and an advisor in SCS to guide their focus in computer science.

BCSA Curriculum

	Units
I. BCSA General Education	**122**
II. SCS Concentration	**117**
III. CFA Concentration	**108-130**
IV. Free Electives	**11-33**
Total BCSA Degree Requirements	**380**

BCSA General Education

(15 courses, 122 units minimum)

- Writing (1 course, 9 units, 76-101 required)
- Mathematics (2 courses, 20 units minimum, 21-122 and either 21-259, 21-266 or 21-241 required), Probability (1 course, 9 units minimum)
- Science & Engineering (2 courses, 18 units minimum)
- Economic, Political, & Social Institutions OR Cognition, Choice & Behavior (1 course, 9 units minimum)
- Two additional courses from Dietrich or CFA (2 course, 18 units minimum)
- University Requirement (1 course, 3 units, 99-101 required)
- BXA Required Courses (5 courses, 36 units, 52-190, 52-291, 52-392, 52-401, 52-402)

Writing (1 course, 9 units)

Broadly considered, language is a tool used to communicate, as well as a way to organize non-visual and non-mathematical thinking. This requirement focuses on the social nature of language and the ways in which writing constitutes thinking.

76-101	Interpretation and Argument -First-year	9
or 76-102	Advanced First Year Writing: Special Topics	
or 76-106 & 76-107 & 76-108	Writing about Literature, Art and Culture and Writing about Data and Writing about Public Problems	

All undergraduate students must complete the First-Year Writing requirement—the Department of English does not accept any Advanced Placement exemptions. This requirement can be completed in two different ways. Enroll in one of two full-semester courses 101 or 102 (by invitation only), 9 units, or enroll in two of three half-semester mini courses (back-to-back within a single semester) 106/107/108, 4.5 + 4.5 units. Course options and topics: www.cmu.edu/hss/english/first_year/index.html

Mathematics & Probability (3 courses, 29 units minimum)

Choose two mathematics courses (20 units minimum):

21-122	Integration and Approximation	10
21-259	Calculus in Three Dimensions	10
or 21-266	Vector Calculus for Computer Scientists	
or 21-241	Matrices and Linear Transformations	

Choose one probability course(s) (9 units minimum):

15-259	Probability and Computing	12
21-325	Probability	9
36-218	Probability Theory for Computer Scientists	9
36-225-36-226	Introduction to Probability Theory - Introduction to Statistical Inference	18

Science & Engineering (2 courses, 18 units minimum)

Choose two science courses from differing departments or one science and one engineering course from the following list:

03-121	Modern Biology	9
03-125	Evolution	9
03-132	Basic Science to Modern Medicine	9
03-133	Neurobiology of Disease	9
03-135	Structure and Function of the Human Body	9
03-140	Ecology and Environmental Science	9
03-161	Molecules to Mind	9
06-100	Introduction to Chemical Engineering	12
09-105	Introduction to Modern Chemistry I	10
09-106	Modern Chemistry II *	10
09-225	Climate Change: Chemistry, Physics and Planetary Science *	9
12-100	Exploring CEE: Infrastructure and Environment in a Changing World	12
12-201	Geology	9
12-351	Environmental Engineering *	9
18-095	Getting Started in Electronics: An Experiential Approach	9
18-100	Introduction to Electrical and Computer Engineering	12
18-220	Electronic Devices and Analog Circuits *	12
18-240	Structure and Design of Digital Systems *	12
24-101	Fundamentals of Mechanical Engineering	12
24-292	Renewable Energy Engineering *	9
24-358	Culinary Mechanics	9
24-381	Environmental Systems on a Changing Planet	12
27-215	Thermodynamics of Materials	12
33-114	Physics of Musical Sound	9
33-120	Science and Science Fiction	9
33-121	Physics I for Science Students *	12
or 33-141	Physics I for Engineering Students	
33-224	Stars, Galaxies and the Universe *	9
33-225	Quantum Physics and Structure of Matter *	9
33-226	Physics of Energy *	9
42-101	Introduction to Biomedical Engineering	12
42-202	Physiology *	9
85-219	Foundations of Brain and Behavior	9
Labs:		
02-261	Quantitative Cell and Molecular Biology Laboratory *	Var.
03-124	Modern Biology Laboratory	9
27-100	Engineering the Materials of the Future *	12
33-104	Experimental Physics	9
42-203	Biomedical Engineering Laboratory *	9

Economic, Political & Social Institutions OR Cognition, Choice & Behavior (1 course from either category, 9 units minimum)

Economic, Political & Social Institutions

This requirement explores the processes by which institutions organize individual preferences and actions into collective outcomes.

19-101	Introduction to Engineering and Public Policy	12
36-303	Sampling, Survey and Society *	9
66-221	Topics of Law: Introduction to Intellectual Property Law	9
70-332	Business, Society and Ethics *	9
73-102	Principles of Microeconomics	9
or 73-104	Principles of Microeconomics Accelerated	
73-103	Principles of Macroeconomics *	9
76-425	Rhetoric, Science, and the Public Sphere *	9
79-101	Making History: How to Think About the Past (and Present)	9
79-189	Democracy and History: Thinking Beyond the Self	9
79-237	Comparative Slavery	9
79-244	Women in American History	9
79-253	Imperialism and Decolonization in South Asia	9
79-300	Controversial Topics in the History of American Public Policy	9
79-320	Women, Politics, and Protest	9
79-321	Documenting Human Rights	9
79-331	Body Politics: Women and Health in America	9
79-370	Technology in the United States	9
79-383	The History of Capitalism	9
79-391	Nations and Nationalisms in South Asia	9
79-392	Europe and the Islamic World	9
80-135	Introduction to Political Philosophy	9
80-136	Social Structure, Public Policy & Ethics	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-324	Philosophy of Economics	9
80-334/335	Social and Political Philosophy	9
80-348	Health, Human Rights, and International Development	9
84-104	Decision Processes in American Political Institutions	9
84-110	The Economics of Politics, Policy, and Technology	9
84-275	Comparative Politics	9
84-322	Nonviolent Conflict and Revolution	9
84-324	The Future of Democracy	9
84-352	Representation and Voting Rights	9
84-362	Diplomacy and Statecraft	9
84-365	The Politics of Fake News and Misinformation	9
84-380	US Grand Strategy	9
84-386	The Privatization of Force	9
84-387	Remote Systems and the Cyber Domain in Conflict	9
84-389	Terrorism and Insurgency	9
84-390	Social Media, Technology, and Conflict	9
84-393	Legislative Decision Making: US Congress *	9
84-402	Judicial Politics and Behavior *	9
84-405	The Future of Warfare	9
88-281	Topics in Law: 1st Amendment	9
88-284	Topics of Law: The Bill of Rights	9

Cognition, Choice, and Behavior

This requirement explores the process of thinking, decision making, and behavior in the context of the individual.

70-311	Organizational Behavior *	9
70-318	Managing Effective Work Teams *	9

70-385	Consumer Behavior *	9
80-101	Dangerous Ideas in Science and Society	9
80-130	Introduction to Ethics	9
80-150	Nature of Reason	9
80-180	Nature of Language: An Introduction to Linguistics	9
80-221	Philosophy of Social Science	9
80-252	Kant	9
80-270	Problems of Mind and Body: Meaning and Doing	9
80-271	Mind and Body: The Objective and the Subjective	9
80-275	Metaphysics	9
80-330	Ethical Theory	9
85-102	Introduction to Psychology	9
85-104	Psychopathology	9
85-211	Cognitive Psychology	9
85-213	Human Information Processing and Artificial Intelligence *	9
85-221	Principles of Child Development	9
85-241	Social Psychology	9
85-251	Personality	9
85-261	Psychopathology	9
85-370	Perception	9
85-408	Visual Cognition *	9
85-414	Cognitive Neuropsychology *	9
85-421	Language and Thought *	9
88-120	Reason, Passion and Cognition	9
88-230	Human Intelligence and Human Stupidity	9
88-231	Thinking in Person vs. Thinking Online	9

** Indicates co-requisites and/or prerequisites required.*

Additional Dietrich College Courses (2 courses, 18 units minimum)

Complete two non-technical courses. Consult with your BXA advisor to determine the best courses to fulfill this requirement.

University Requirement (1 course, 3 units)

This foundational pass/no pass course is to be completed online in the first semester to develop core competency skills.

99-101	Core@CMU -Fall, First-year (section B; pass/no pass)	3

BXA Required Courses (5 courses, 36 units)

BXA-specific courses give students the opportunity to integrate their areas of concentration by focusing on interdisciplinary approaches and arts-based research techniques.

52-190	BXA Seminar I: Building the Wunderkammer - Spring, First-year (mini-3)	4.5
52-291	BXA Seminar II: Transferring Knowledge -Spring, Sophomore year (mini-4)	4.5
52-392	BXA Seminar III: Deconstructing Disciplines - Spring, Junior year	9
52-401	BXA Seminar IV: Capstone Project Research -Fall, Senior year	9
52-402	BXA Seminar V: Capstone Project Production - Spring Senior year	9

School of Computer Science Concentration

Computer Science Concentration

(11courses, 117 units minimum)

Prerequisite

15-112	Fundamentals of Programming and Computer Science	12

Computer Science Core Requirements (5 courses, 60 units)

15-122	Principles of Imperative Computation	12
15-150	Principles of Functional Programming	12
15-210	Parallel and Sequential Data Structures and Algorithms	12
15-213	Introduction to Computer Systems	12
15-251	Great Ideas in Theoretical Computer Science	12

Concepts of Mathematics (1 course, 12 units)

21-127	Concepts of Mathematics (co-requisite for 15-122; prerequisite for 15-150)	12

Note: First-year BCSA students may opt for 15-151 if offered, in place of 21-127.

Applications Courses or CS Electives (5 courses, 45 units minimum)

Choose a minimum of five courses from SCS beyond the core requirements, 200-level or higher, not including 02-223, 02-261, 15-351, 16-223, 17-200 (or cross listed numbers), 17-333, 17-562. Listed below are suggested choices for these electives. Consult with the CS advisor if interested in courses not listed.

05-391	Designing Human Centered Software	12
05-318	Human AI Interaction	12
05-319	Data Visualization	12
05-320	Social Web	12
05-360	Interaction Design Fundamentals	12
05-418	Design Educational Games	12
05-430	Programming Usable Interfaces	15
10-301	Introduction to Machine Learning	12
10-335	Art and Machine Learning	12
11-324	Human Language for Artificial Intelligence	12
11-344	Machine Learning in Practice	12
11-411	Natural Language Processing	12
15-281	Artificial Intelligence: Representation and Problem Solving	12
15-322	Introduction to Computer Music	9
15-362	Computer Graphics	12
15-367	Algorithmic Textiles Design	12
15-388	Practical Data Science	9
15-415	Database Applications	12
15-451	Algorithm Design and Analysis	12
15-463	Computational Photography	12
15-464	Technical Animation	12
15-465	Animation Art and Technology	12
15-466	Computer Game Programming	12
15-494	Cognitive Robotics: The Future of Robot Toys	12
16-220	Robot Building Practices	12
16-264	Humanoids	12
16-362	Mobile Robot Algorithms Laboratory	12
16-376	IDeATe: Kinetic Fabrics	10
16-385	Computer Vision	12
16-467	Introduction to Human Robot Interaction	12
16-480	IDeATe: Creative Soft Robotics	10
17-214	Principles of Software Construction: Objects, Design, and Concurrency	12
17-313	Foundations of Software Engineering	12
17-356	Software Engineering for Startups	12
17-437	Web Application Development	12

COLLEGE OF FINE ARTS CONCENTRATION

(number of courses vary, 108-130 units minimum)

BCSA students choose one of the following concentrations:

- Architecture (108 units)
- Art (114 units)
- Design (108 units)
- Drama (130 units)
- Music (108 units)

Architecture Concentration

(108 units minimum)

Architecture Required Courses (9 courses, 57 units minimum)

48-100	Architecture Design Studio: POIESIS STUDIO 1 - Fall, Freshman or Sophomore year	10-15
or 48-095	Spatial Concepts for Non-Architecture Majors	
48-104	Shop Skills -Fall, Freshman year	2
62-104	Design Ethics & Social Justice in Architecture - Fall, Freshman or Sophomore year	3
62-122	Digital Media I -Fall, Freshman year	6
62-125	Drawing I -Fall, Freshman year	6
62-123	Digital Media II -Spring, Freshman year	6
62-126	Drawing II -Spring, Freshman year	6
48-240	History of World Architecture, I -Spring, Freshman year	9
48-241	History of Modern Architecture -Fall, Sophomore year	9

Architecture Electives (51 units minimum)

A minimum of **51** additional Architecture units must be approved by the Architecture advisor. A list of these selected courses must be filed in the BXA office. 48-025 First Year Seminar: Architecture Edition I (3 units) is recommended in fall of the first year.

Art Concentration

(114 units minimum)

First-Year Seminar (1 course, 6 units)

60-104	Foundations: Art First-Year Seminar	6

Foundation Studios (3 courses, 30 units)

Complete three courses:

60-110	Foundations: Time-Based Media	10
60-120	Foundations: Digital Media	10
60-131	Foundations: Sculpture	10
60-135	Foundations: Sculpture II	10
60-150	Foundations: Drawing	10
60-170	Foundations: Paint/Print	10

Intermediate Studios (3 courses, 30 units)

Complete three courses:

60-2xx	Intermediate Studio Elective	10
60-2xx	Intermediate Studio Elective	10
60-2xx	Intermediate Studio Elective	10

Advanced Studios (3 courses, 30 units)

Students may take courses in any media area (ETB, SIS, CP or DP3). They may take all courses in one media area if a focus is desired. With approval from the Art advisor, BXA students can take an additional intermediate studio in lieu of an advanced studio to increase breadth.

Complete three courses:

60-401/402	Senior Studio	10
60-403	Senior Critique Seminar	10
Advanced Electronic and Time-Based Work (ETB) (course numbers 60-410 through 60-429) *		10
Advanced Sculpture, Installation and Site-Work (SIS) (course numbers 60-430 through 60-447) *		10
Advanced Contextual Practice (CP) (course numbers 60-448 through 60-449) *		10
Advanced Drawing, Painting, Print Media and Photography (DP3) (course numbers 60-450 through 60-498) *		10
60-499	Studio Independent Study (one only)	10

* *Courses offered intermittently; speak with a BXA advisor to determine course availability.*

Critical Studies (2 courses, 18 units)

60-107	Foundations: Critical Studies -Spring	9
60-3xx	Critical Studies Elective	9

Review Requirement (1 required review, 0 units)

Complete required review:

60-200	Sophomore Review -Spring (pass/no pass)	0

Design Concentration

(108 units minimum)

Note: BXA design only considers internal transfer applicants currently enrolled in Design.

Design Required Courses (16 courses, 98 units)

51-101	Studio: Survey of Design -Fall, First-year	10
51-121	Visualizing -Fall, First-year	10
51-175	Design Studies: Place -Fall, First-year (mini-1)	5
51-177	Design Studies: Histories -Fall, First-year (mini-2)	5
51-102	Design Lab -Spring, First-year	10
51-122	Collaborative Visualizing -Spring, First-year	10
51-176	Design Studies: Futures -Spring, First-year (mini-3)	5
51-178	Design Studies: Experience -Spring, First-year (mini-4)	5
51-277	Design Studies: Systems -Fall, Sophomore year (mini-1)	5
51-279	Design Studies: Cultures -Fall, Sophomore year (mini-2)	5
51-282	Design Studies: Persuasion -Spring, Sophomore year (mini-3)	5
51-284	Design Studies: Power -Spring, Sophomore year (mini-4)	5
Choose Two Studios -Fall, Sophomore year:		4.5+4.5
51-225	Communications Studio I: Understanding Form & Context	4.5
or 51-245	Products Studio I: Understanding Form & Context	
or 51-265	Environments Studio I: Understanding Form & Context	
Choose Two Corresponding Labs -Fall, Sophomore year:		4.5+4.5
51-227	Prototyping Lab I: Communications	4.5
or 51-247	Prototyping Lab I: Products	
or 51-267	Prototyping Lab I: Environments	

Design Electives (10 units)

A minimum of **10** additional Design units must be approved by the Design advisor. A list of these selected courses must be filed in the BXA office.

Drama Concentration

(130 units minimum)

Options available in the following areas: 1) Design, 2) Dramaturgy, 3) Production Technology and Management

Note: BXA design only considers internal transfer applicants currently enrolled in Drama design. BXA dramaturgy only considers internal transfer applicants in the fall semester for spring enrollment, unless currently enrolled in Drama dramaturgy. BXA PTM only considers internal transfer applicants currently enrolled in Drama PTM.

Design/PTM Required Courses (10 courses, 75 units)

54-169	Studiocraft 1 -Fall, First-year	13
54-151	Stagecraft -Fall, First-year	6
54-159	Production Practicum -Fall, First-year	6
54-171	Basic Design 1 -Fall, First-year	6
54-170	Studiocraft 2 -Spring, First-year	8
54-152	Stagecraft -Spring, First-year	12
54-158	Production Planning -Spring, First-year	6
54-177	Foundations of Drama I -Spring, First-year or later if needed	6
54-281	Foundations of Drama II	6
54-381	Special Topics: Feminist Theatre	6

Design/PTM Required Courses (55 units minimum)

A minimum of **55** additional Design/PTM units taken in the sophomore year or later must be approved by the Design/PTM faculty area chair. A list of these selected courses must be filed in the BXA office.

Dramaturgy Required Courses (13 courses, 80 units)

54-177	Foundations of Drama I -Fall, First-year	6
54-109	Dramaturgy 1: Approaches to Text -Fall, First-year	9
54-284	Fundamentals of Directing -Fall, First-year	6
54-200	Dramaturgy Forum -Fall, First-year	1

54-159	Production Practicum -Fall or Spring, First-year	6
54-281	Foundations of Drama II -Spring, First-year	6
54-184	Dramaturgy 2: Introduction to Production Dramaturgy -Spring, First-year	9
54-200	Dramaturgy Forum -Spring, First-year	1
54-117	Design Collaboration Project -Spring, First-year	3
54-241	Dramaturgy 3: Dramaturgy in Translation -Fall, Sophomore year	9
54-256	Dramaturgy 4: New Play Dramaturgy -Spring, Sophomore year	9
54-363	Dramaturgy 5 -Fall, Junior year	9
54-381	Special Topics: Feminist Theatre	6

Dramaturgy Electives (50 units minimum)

A minimum of **50** additional Dramaturgy units taken in the sophomore year or later must be approved by the Dramaturgy faculty area chair. A list of these selected courses must be filed in the BXA office.

Music Concentration

(108 units minimum)

Options available in the following areas: 1) Audio Recording & Production, 2) Composition, 2) Music Performance (instrumental, organ, piano, voice), 4) Sound Theory & Practice

Note: BXA music performance only considers internal transfer applicants in the spring semester for fall enrollment, unless currently enrolled in Music performance.

Audio Recording & Production Required Courses (8 courses, 49 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-101	Introduction to Music Technology	6
or 57-171	Introduction to Music Technology (self-paced)	
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-438	Multitrack Recording	9

Audio Recording & Production Electives (59 units minimum)

Choose **59** units from:

57-153	Harmony II	9
or 57-150	Basic Harmony II	
57-182	Solfege II	3
or 57-186	Advanced Solfege II	
10-301	Introduction to Machine Learning	12
15-104	Introduction to Computing for Creative Practice	10
15-213	Introduction to Computer Systems	12
15-322	Introduction to Computer Music	9
18-090	Twisted Signals: Multimedia Processing for the Arts	10
33-114	Physics of Musical Sound	9
54-166	Introduction to Sound Design for Theatre	6
54-666	Production Audio (section B)	4
57-161	Eurhythmics I	3
57-162	Eurhythmics II	3
57-344	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music	6
57-358	Introduction to Electronic Music (with instructor permission as space allows)	9
57-421	Exploded Ensemble	6
57-427	Advanced Seminar in Film Musicology	9
57-478	Survey of Historical Recording	6
57-622	Independent Study in Sound Recording Production	3
60-131	Foundations: Sculpture	10
85-385	Auditory Perception: Sense of Sound	9

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Audio Recording & Production concentration.

Composition Required Courses (13 courses, 85 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-161	Eurhythmics I (recommended co-requisite: 57-181)	3
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-49x	BXA Studio (4 semesters)	36
57-xxx	Major Ensemble (4 semesters)	24

Composition Electives (23 units minimum)

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Music Performance Required Courses (13 courses, 85 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-161	Eurhythmics I (recommended co-requisite: 57-181)	3
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-49x	BXA Studio (4 semesters)	36
57-xxx	Major Ensemble (4 semesters)	24

Music Performance Electives (23 units minimum)

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Sound Theory & Practice Required Courses (8 courses, 53 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-101	Introduction to Music Technology	6
or 57-171	Introduction to Music Technology (self-paced)	
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
18-090	Twisted Signals: Multimedia Processing for the Arts	10
57-421	Exploded Ensemble	6
57-911	Music Since 1945	9

Sound Theory & Practice Electives (55 units minimum)

Choose **55** units from:

57-153	Harmony II	9
or 57-150	Basic Harmony II	
57-182	Solfege II	3
or 57-186	Advanced Solfege II	
15-104	Introduction to Computing for Creative Practice	10
15-322	Introduction to Computer Music (prerequisite: 15-112)	9
33-114	Physics of Musical Sound	9
57-161	Eurhythmics I	3
57-162	Eurhythmics II	3
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6

57-343	Music, Technology, and Culture	9
57-344	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music (prerequisite: 57-101 or 57-171)	6
57-358	Introduction to Electronic Music (with instructor permission as space allows)	9
57-438	Multitrack Recording	9
57-478	Survey of Historical Recording	6
57-616	Independent Study in Sound Studies	9

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Sound Theory & Practice concentration.

Free Electives

(approximately 2-4 courses, 11-33 units minimum)

Take any Carnegie Mellon course. A maximum of 9 units of physical education and/or military science may be counted toward this requirement.

Bachelor of Engineering Studies and Arts Degree Program

The Bachelor of Engineering Studies and Arts (BESA) intercollege degree program combines the strengths of the College of Fine Arts (CFA) and the College of Engineering (ENG). This degree is tailored for students seeking to apply knowledge from duel fields to advance maker culture in novel and creative ways. Students choose their arts concentration from the following schools in CFA: Architecture, Art, Design, Drama or Music. Students choose their engineering studies concentration established by the College of Engineering. Options within the concentration include: biomedical engineering, chemical engineering, civil & environmental engineering, electrical & computer engineering, materials science & engineering or mechanical engineering.

The BESA curriculum has three main components: general education requirements, fine arts concentration requirements and engineering studies concentration requirements. Each student's course of study is structured so they can complete this rigorous program in four years.

Students receive extensive advising support. The academic advisors in the BXA Intercollege Degree Programs are the primary advisors and liaisons between CFA and ENG. Each student has two additional academic advisors: an advisor in the admitting school of CFA to guide their focus in the arts and an advisor in ENG to guide their focus in engineering studies.

BESA Curriculum

	Units
I. BESA General Education	**92**
II. ENG Concentration	**93-120**
III. CFA Concentration	**108-130**
IV. Free Electives	**38-87**
Total BESA Degree Requirements	**380**

BESA GENERAL EDUCATION

(11 courses, 92 units minimum)

- Writing (1 course, 9 units, 76-101 required)
- Mathematics (2 courses, 20 units, 21-120 and 21-122 required)
- Science and Technology (2 courses, 24 units, 15-112 and 33-141 required)
- University Requirement (1 course, 3 units, 99-101 required)
- BXA Required Courses (5 courses, 36 units, 52-190, 52-291, 52-392, 52-401, 52-402)

Writing (1 course, 9 units)

76-101	Interpretation and Argument -First-year	9
or 76-102	Advanced First Year Writing: Special Topics	
or 76-106 & 76-107 & 76-108	Writing about Literature, Art and Culture and Writing about Data and Writing about Public Problems	

All undergraduate students must complete the First-Year Writing requirement—the Department of English does not accept any Advanced Placement exemptions. This requirement can be completed in two different ways. Enroll in one of two full-semester courses 101 or 102 (by invitation only), 9 units, or enroll in two of three half-semester mini courses (back-to-back within a single semester) 106/107/108, 4.5 + 4.5 units. Course options and topics: www.cmu.edu/hss/english/first_year/index.html

Mathematics (2 courses, 20 units)

21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10

Science and Technology (2 courses, 24 units)

15-112	Fundamentals of Programming and Computer Science (15-110 or 15-112 for MechE concentration option only)	12
33-141	Physics I for Engineering Students	12

University Requirement (1 course, 3 units)

This foundational pass/no pass course is to be completed online in the first semester to develop core competency skills.

99-101	Core@CMU -Fall, First-year (section B; pass/no pass)	3

BXA Required Courses (5 courses, 36 units)

BXA-specific courses give students the opportunity to integrate their areas of concentration by focusing on interdisciplinary approaches and arts-based research techniques.

52-190	BXA Seminar I: Building the Wunderkammer - Spring, First-year (mini-3)	4.5
52-291	BXA Seminar II: Transferring Knowledge -Spring, Sophomore year (mini-4)	4.5
52-392	BXA Seminar III: Deconstructing Disciplines - Spring, Junior year	9
52-401	BXA Seminar IV: Capstone Project Research -Fall, Senior year	9
52-402	BXA Seminar V: Capstone Project Production - Spring, Senior year	9

College of Engineering Concentration

(number of courses vary, 93-120 units)

BESA students declare one of the following concentrations, through consultation with their BXA advisor and the ENG concentration advisors. A completed ENG Concentration Declaration form must be approved by the concentration advisor and submitted to the BXA office, by spring mid-semester break of the student's first year.

- Biomedical Engineering (93 units)
- Chemical Engineering (102 units)
- Civil Engineering (99 units)
- Electrical & Computer Engineering (120 units)
- Environmental Engineering (95 units)
- Materials Science & Engineering (99 units)
- Mechanical Engineering (105 units)

BESA students who are admitted as freshmen are undeclared until they have met with a concentration advisor and have submitted their signed Declaration form. BESA students who are admitted through internal transfer must have chosen an ENG concentration at the time of their application (which serves as declaration). All BESA students wishing to change their ENG concentration at any time following the initial declaration must meet with the advisor of their intended concentration area to complete a new Declaration form.

Biomedical Engineering Concentration

(93 units minimum)

Mathematics & Science Prerequisites

21-120	Differential and Integral Calculus -(Gen Ed)	10
21-122	Integration and Approximation -(Gen Ed)	10
21-254	Linear Algebra and Vector Calculus for Engineers	11
21-260	Differential Equations	9
15-110	Principles of Computing	10
33-141	Physics I for Engineering Students -(Gen Ed)	12
33-142	Physics II for Engineering and Physics Students	12
03-121	Modern Biology	9

Biomedical Engineering Courses (7 courses, 66 units)

42-101	Introduction to Biomedical Engineering -First-year	12
xx-xxx	2nd Introduction to Engineering course, student’s choice	12
42-202	Physiology -Sophomore year; prereq: 03-121/03-151	9
42-203	Biomedical Engineering Laboratory -Sophomore year; prereq: 42-101, 03-121/03-151	9
42-302	Biomedical Engineering Systems Modeling and Analysis -Junior year; prereq: 06-262/18-202/21-260	9
42-401	Foundation of BME Design -Fall, Senior year; prereq: 42-101	6
42-402	BME Design Project -Spring, Senior year	9

Electives (3 courses, 27 units minimum)

Choose 3 elective courses in BME tracks and/or ENG with prerequisites in consultation with the concentration advisor.

Chemical Engineering

(102 units minimum)

Mathematics & Science Prerequisites

21-120	Differential and Integral Calculus -(Gen Ed)	10
21-122	Integration and Approximation -(Gen Ed)	10
21-254	Linear Algebra and Vector Calculus for Engineers -Fall, Sophomore year	11
15-110	Principles of Computing	10
33-141	Physics I for Engineering Students -(Gen Ed)	12
33-142	Physics II for Engineering and Physics Students	12
09-105	Introduction to Modern Chemistry I	10
09-106	Modern Chemistry II	10

Chemical Engineering Courses (7 courses, 75 units)

06-100	Introduction to Chemical Engineering -First-year; co-req: 09-105, 21-120	12
xx-xxx	2nd Introduction to Engineering course, student’s choice	12
06-223	Chemical Engineering Thermodynamics -Fall, Sophomore year; prereq: 06-100, 33-121/33-141/ 33-151	12
06-261	Fluid Mechanics -Spring, Sophomore year; prereq: 06-223, 21-254	9
06-262	Mathematical Methods of Chemical Engineering -Spring, Sophomore year; prereq: 06-223, 21-254	12
06-323	Heat and Mass Transfer -Fall, Junior year; prereq: 06-261, 06-262/21-260, 33-122/33-142/33-152	9
06-361	Unit Operations of Chemical Engineering -Spring, Junior year; prereq: 06-323	9

Electives (3 courses, 27 units minimum)

Choose 27 units from the following ChemE and/or ENG courses with prerequisites in consultation with the concentration advisor:

06-310	Molecular Foundations of Chemical Engineering -Fall, Junior year; prereq: 06-223, 09-106	9
06-325	Numerical Methods and Machine Learning for Chemical Engineering -Fall, Junior year; prereq: 06-262, 15-110/15-112	6
06-326	Optimization Modeling and Algorithms -Fall, Junior year; prereq: 06-262	6
06-363	Transport Process Laboratory -Spring, Junior year; prereq: 06-261, 06-323	9
06-364	Chemical Reaction Engineering -Spring, Junior year; prereq: 06-310, 06-323	9
06-607	Physical Chemistry of Colloids and Surfaces -Senior year	9
06-609	Physical Chemistry of Macromolecules -Fall, Senior year	9
27-xxx	Materials Science course	9

Note: With advisor approval, electives can instead be other ChemE/ENG courses as long as they are taken in proper order to follow the required prerequisites, not allowing 06-421.

Civil Engineering

(99 units minimum)

Mathematics & Science Prerequisites

21-120	Differential and Integral Calculus -(Gen Ed)	10
21-122	Integration and Approximation -(Gen Ed)	10
21-254	Linear Algebra and Vector Calculus for Engineers	11
21-260	Differential Equations	9
15-110	Principles of Computing	10
33-141	Physics I for Engineering Students -(Gen Ed)	12
33-142	Physics II for Engineering and Physics Students	12
09-105	Introduction to Modern Chemistry I	10
or 09-111	Nanolegos: Chemical Building Blocks	

Civil Engineering Courses (9 courses, 72 units)

12-100	Exploring CEE: Infrastructure and Environment in a Changing World -First-year; co-req: 21-120, 33-141	12
xx-xxx	2nd Introduction to Engineering course, student’s choice	12
12-200	CEE Challenges: Design in a Changing World -Fall, Sophomore year; prereq: 12-100	9
12-212	Statics -Fall, Sophomore year; co-req: 12-100, 21-122, 33-141	9
12-233	CEE Infrastructure Systems in Action -Fall, Sophomore year; prereq: 12-100	2
12-231	Solid Mechanics -Spring, Sophomore year; prereq: 12-212	9
12-234	Sensing and Data Acquisition for Engineering Systems -Spring, Sophomore year	4
12-271	Computation and Data Science for Civil & Environmental Engineering -Spring, Sophomore year; prereq: 15-110/15-112, 21-120, 21-122, 33-141	9
27-357	Introduction to Materials Selection -Spring, Junior year	6

Electives (3 courses, 27 units minimum)

Choose 27 units from the following CivE courses with prerequisites in consultation with the concentration advisor:

12-201	Geology -Sophomore year	9
12-301	CEE Projects: Integrating the Built, Natural and Information Environments -Fall, Junior year; prereq: 12-200, 12-271	9
12-335	Soil Mechanics -Fall, Junior year; prereq: 12-231, 33-142; co-req: 12-355	9
12-355	Fluid Mechanics -Fall, Junior year; prereq: 21-260	9
12-356	Fluid Mechanics Lab -Fall, Junior year; co-req: 12-355	2
12-351	Environmental Engineering -Spring, Junior year; prereq: 09-105/09-111; co-req: 21-260	9
12-635	Structural Analysis -Fall, Senior year; prereq: 12-231	12
12-631	Structural Design -Spring, Senior year: prereq: 12-231; co-req: 27-357, 12-358	12

Electrical & Computer Engineering

(120 units minimum)

Mathematics & Science Prerequisites

21-120	Differential and Integral Calculus -(Gen Ed)	10
21-122	Integration and Approximation -(Gen Ed)	10
21-127	Concepts of Mathematics	12
15-112	Fundamentals of Programming and Computer Science	12
15-122	Principles of Imperative Computation	12
33-141	Physics I for Engineering Students -(Gen Ed)	12
33-142	Physics II for Engineering and Physics Students	12

Electrical & Computer Engineering Courses (7 courses, 84 units)

18-100	Introduction to Electrical and Computer Engineering -First-year; co-req: 21-120	12
xx-xxx	2nd Introduction to Engineering course, student’s choice	12
18-202	Mathematical Foundations of Electrical Engineering -Sophomore year; prereq: 21-122 *	12
18-213	Introduction to Computer Systems -Sophomore year; prereq: 15-122	12
18-220	Electronic Devices and Analog Circuits -Sophomore year; prereq: 18-100; co-req: 33-142	12
18-240	Structure and Design of Digital Systems -Sophomore year; prereq: 18-100	12
18-290	Signals and Systems -Sophomore year; prereq: 18-100	12

* *This course can also be substituted by a combination of two of the following courses: 21-254, 21-259, 21-260, 21-241, 21-242, 21-268.*

Electives (3 courses, 36 units minimum)

Choose 3 elective courses 18-3xx and above. At least 2 courses should be Area Courses from 1 of the 5 Areas within ECE and 1 course may be an additional Area Course from a second Area, a Coverage Course or ENG with prerequisites in consultation with the concentration advisor.

Environmental Engineering

(95 units minimum)

Mathematics & Science Prerequisites

21-120	Differential and Integral Calculus -(Gen Ed)	10
21-122	Integration and Approximation -(Gen Ed)	10
21-254	Linear Algebra and Vector Calculus for Engineers	11
21-260	Differential Equations	9
15-110	Principles of Computing	10
33-141	Physics I for Engineering Students -(Gen Ed)	12
33-142	Physics II for Engineering and Physics Students	12
09-105	Introduction to Modern Chemistry I	10
or 09-111	Nanolegos: Chemical Building Blocks	

Environmental Engineering Courses (10 courses, 77 units)

12-100	Exploring CEE: Infrastructure and Environment in a Changing World -First-year; co-req: 21-120, 33-141	12
xx-xxx	2nd Introduction to Engineering course, student’s choice	12
12-200	CEE Challenges: Design in a Changing World -Fall, Sophomore year; prereq: 12-100	9
12-221	Environmental Chemistry and Thermodynamics -Fall, Sophomore year; prereq: 09-105/09-111	9
12-222	Environmental Chemistry Laboratory -Fall, Sophomore year; co-req: 09-101, 12-221	3
12-271	Computation and Data Science for Civil & Environmental Engineering -Spring, Sophomore year; prereq: 15-110/15-112, 21-120, 21-122, 33-141	9
12-351	Environmental Engineering -Spring, Junior year; prereq: 09-105/09-111; co-req: 21-260	9
12-352	Environmental Engineering Lab -Spring, Junior year; co-req: 12-351	3
12-355	Fluid Mechanics -Fall, Junior year; prereq: 21-260	9
12-356	Fluid Mechanics Lab -Fall, Junior year; co-req: 12-355	2

Electives (2 courses, 18 units minimum)

Choose 18 units from the following EE courses with prerequisites in consultation with the concentration advisor:

12-201	Geology -Sophomore year	9
12-301	CEE Projects: Integrating the Built, Natural and Information Environments -Fall, Junior year; prereq: 12-200 and 12-271	9
12-353	Environmental Biology and Ecology -Spring, Junior year	9
12-612	Intro to Sustainable Engineering -Fall, Senior year	9
12-657	Water Resource Systems Engineering -Fall, Senior year; prereq: 12-355; co-req: 12-351	9
03-121	Modern Biology	9

Materials Science & Engineering

(99 units minimum)

Mathematics & Science Prerequisites

21-120	Differential and Integral Calculus -(Gen Ed)	10
21-122	Integration and Approximation -(Gen Ed)	10
21-254	Linear Algebra and Vector Calculus for Engineers	11
21-260	Differential Equations	9
15-110	Principles of Computing	10
33-141	Physics I for Engineering Students -(Gen Ed)	12
33-142	Physics II for Engineering and Physics Students	12
09-105	Introduction to Modern Chemistry I	10

Materials Science & Engineering Courses (8 courses, 72 units)

27-100	Engineering the Materials of the Future -First-year; co-req: 21-120, 33-141	12
xx-xxx	2nd Introduction to Engineering course, student’s choice	12
27-211	Structure of Materials (Minor Option) -Fall, Sophomore year *	6
27-212	Defects in Materials (Minor Option) -Spring, Sophomore year *	6
27-215	Thermodynamics of Materials -Fall, Sophomore year; co-req: 27-100, 21-259	12
27-216	Transport in Materials -Spring, Sophomore year; prereq: 27-215	9
27-227	Phase Relations and Diagrams (Minor Option) -Spring, Sophomore year *	9
27-357	Introduction to Materials Selection -Spring, Sophomore year	6

* *In consultation with the concentrations advisor, students may choose to complete the version of the course with lab component.*

Electives (3 courses, 27 units minimum)

Choose 3 elective courses in MSE and/or ENG with prerequisites in consultation with the concentration advisor.

Mechanical Engineering

(105 units minimum)

Mathematics & Science Prerequisites

21-120	Differential and Integral Calculus -First-year (Gen Ed)	10
21-122	Integration and Approximation -First-year (Gen Ed)	10
21-254	Linear Algebra and Vector Calculus for Engineers	11
21-260	Differential Equations	9
15-110	Principles of Computing -(Gen Ed)	10
33-141	Physics I for Engineering Students -First-year (Gen Ed)	12
33-142	Physics II for Engineering and Physics Students -First-year	12

Note: The BESA Gen Ed Science and Technology requirement can be filled with either 15-110 or 15-112. Students may start taking MechE Courses upon completion of Calculus I, Calculus II and Physics I.

Mechanical Engineering Courses (7 courses, 60 units)

24-101	Fundamentals of Mechanical Engineering -First-year; co-req: 21-120, 33-141	12
xx-xxx	2nd Introduction to Engineering course, student's choice	12
24-200	Maker Series: Intro to Manual Machining - Sophomore year	1
24-251	Electronics for Sensing and Actuation - Sophomore year	3
24-261	Mechanics I: 2D Design -Fall, Sophomore year; prereq: 21-122, 33-151/33-141/ 33-121/33-106	10
24-262	Mechanics II: 3D Design -Spring, Sophomore year; prereq: 33-106/33-141/33-151, 24-261	10
24-370	Mechanical Design: Methods and Application - Fall, Junior year; prereq: 24-200, 24-202, 24-262	12

Electives (45 units minimum)

Choose 5 elective courses. Each course should be a minimum of 9 units. At least 3 courses should be from the following MechE courses and 2 of the courses may be ENG with prerequisites in consultation with the concentration advisor.

24-221	Thermodynamics -Fall; prereq: 21-122, 24-101, 33-106/33-121/33-141/33-151	10
24-231	Fluid Mechanics -Spring; prereq: 21-122, 33-106/33-141/33-151	10
24-291	Environmental Systems on a Changing Planet - Fall	9
or 24-381	Environmental Systems on a Changing Planet	
24-292	Renewable Energy Engineering -Spring; prereq: 33-106/33-141	9
24-300	or above	

COLLEGE OF FINE ARTS CONCENTRATION

(number of courses vary, 108-130 units minimum)

BESA students choose one of the following concentrations:

- Architecture (108 units)
- Art (114 units)
- Design (108 units)
- Drama (130 units)
- Music (108 units)

Architecture Concentration

(108 units minimum)

Architecture Required Courses (9 courses, 57 units minimum)

48-100	Architecture Design Studio: POIESIS STUDIO 1 - Fall, Freshman or Sophomore year	10-15
or 48-095	Spatial Concepts for Non-Architecture Majors	
48-104	Shop Skills -Fall, Freshman year	2
62-104	Design Ethics & Social Justice in Architecture - Fall, Freshman or Sophomore year	3
62-122	Digital Media I -Fall, Freshman year	6
62-125	Drawing I -Fall, Freshman year	6
62-123	Digital Media II -Spring, Freshman year	6
62-126	Drawing II -Spring, Freshman year	6
48-240	History of World Architecture, I -Spring, Freshman year	9
48-241	History of Modern Architecture -Fall, Sophomore year	9

Architecture Electives (51 units minimum)

A minimum of **51** additional Architecture units must be approved by the Architecture advisor. A list of these selected courses must be filed in the BXA office. 48-025 First Year Seminar: Architecture Edition I (3 units) is recommended in fall of the first year.

Art Concentration

(114 units minimum)

First-Year Seminar (1 course, 6 units)

60-104	Foundations: Art First-Year Seminar	6

Foundation Studios (3 courses, 30 units)

Complete three courses:

60-110	Foundations: Time-Based Media	10
60-120	Foundations: Digital Media	10
60-131	Foundations: Sculpture	10
60-135	Foundations: Sculpture II	10
60-150	Foundations: Drawing	10
60-170	Foundations: Paint/Print	10

Intermediate Studios (3 courses, 30 units)

Complete three courses:

60-2xx	Intermediate Studio Elective	10
60-2xx	Intermediate Studio Elective	10
60-2xx	Intermediate Studio Elective	10

Advanced Studios (3 courses, 30 units)

Students may take courses in any media area (ETB, SIS, CP or DP3). They may take all courses in one media area if a focus is desired. With approval from the Art advisor, BXA students can take an additional intermediate studio in lieu of an advanced studio to increase breadth.

Complete three courses:

60-401/402	Senior Studio	10
60-403	Senior Critique Seminar	10
Advanced Electronic and Time-Based Work (ETB) (course numbers 60-410 through 60-429) *		10
Advanced Sculpture, Installation and Site-Work (SIS) (course numbers 60-430 through 60-447) *		10
Advanced Contextual Practice (CP) (course numbers 60-448 through 60-449) *		10
Advanced Drawing, Painting, Print Media and Photography (DP3) (course numbers 60-450 through 60-498) *		10
60-499	Studio Independent Study (one only)	10

* *Courses offered intermittently; speak with a BXA advisor to determine course availability.*

Critical Studies (2 courses, 18 units)

60-107	Foundations: Critical Studies -Spring	9
60-3xx	Critical Studies Elective	9

Review Requirement (1 required review, 0 units)

Complete required review:

60-200	Sophomore Review -Spring (pass/no pass)	0

Design Concentration

(108 units minimum)

Note: BXA design only considers internal transfer applicants currently enrolled in Design.

Design Required Courses (16 courses, 98 units)

51-101	Studio: Survey of Design -Fall, First-year	10
51-121	Visualizing -Fall, First-year	10
51-175	Design Studies: Place -Fall, First-year (mini-1)	5
51-177	Design Studies: Histories -Fall, First-year (mini-2)	5
51-102	Design Lab -Spring, First-year	10
51-122	Collaborative Visualizing -Spring, First-year	10
51-176	Design Studies: Futures -Spring, First-year (mini-3)	5
51-178	Design Studies: Experience -Spring, First-year (mini-4)	5
51-277	Design Studies: Systems -Fall, Sophomore year (mini-1)	5
51-279	Design Studies: Cultures -Fall, Sophomore year (mini-2)	5
51-282	Design Studies: Persuasion -Spring, Sophomore year (mini-3)	5
51-284	Design Studies: Power -Spring, Sophomore year (mini-4)	5

Choose Two Studios -Fall, Sophomore year:		4.5+4.5
51-225	Communications Studio I: Understanding Form & Context	4.5
or 51-245	Products Studio I: Understanding Form & Context	
or 51-265	Environments Studio I: Understanding Form & Context	
Choose Two Corresponding Labs -Fall, Sophomore year:		4.5+4.5
51-227	Prototyping Lab I: Communications	4.5
or 51-247	Prototyping Lab I: Products	
or 51-267	Prototyping Lab I: Environments	

Design Electives (10 units)

A minimum of **10** additional Design units must be approved by the Design advisor. A list of these selected courses must be filed in the BXA office.

Drama Concentration

(130 units minimum)

Options available in the following areas: 1) Design, 2) Dramaturgy, 3) Production Technology and Management

Note: BXA design only considers internal transfer applicants currently enrolled in Drama design. BXA dramaturgy only considers internal transfer applicants in the fall semester for spring enrollment, unless currently enrolled in Drama dramaturgy. BXA PTM only considers internal transfer applicants currently enrolled in Drama PTM.

Design/PTM Required Courses (10 courses, 75 units)

54-169	Studiocraft 1 -Fall, First-year	13
54-151	Stagecraft -Fall, First-year	6
54-159	Production Practicum -Fall, First-year	6
54-171	Basic Design 1 -Fall, First-year	6
54-170	Studiocraft 2 -Spring, First-year	8
54-152	Stagecraft -Spring, First-year	12
54-158	Production Planning -Spring, First-year	6
54-177	Foundations of Drama I -Spring, First-year or later if needed	6
54-281	Foundations of Drama II	6
54-381	Special Topics: Feminist Theatre	6

Design/PTM Required Courses (55 units minimum)

A minimum of **55** additional Design/PTM units taken in the sophomore year or later must be approved by the Design/PTM faculty area chair. A list of these selected courses must be filed in the BXA office.

Dramaturgy Required Courses (13 courses, 80 units)

54-177	Foundations of Drama I -Fall, First-year	6
54-109	Dramaturgy 1: Approaches to Text -Fall, First-year	9
54-284	Fundamentals of Directing -Fall, First-year	6
54-200	Dramaturgy Forum -Fall, First-year	1
54-159	Production Practicum -Fall or Spring, First-year	6
54-281	Foundations of Drama II -Spring, First-year	6
54-184	Dramaturgy 2: Introduction to Production Dramaturgy -Spring, First-year	9
54-200	Dramaturgy Forum -Spring, First-year	1
54-117	Design Collaboration Project -Spring, First-year	3
54-241	Dramaturgy 3: Dramaturgy in Translation -Fall, Sophomore year	9
54-256	Dramaturgy 4: New Play Dramaturgy -Spring, Sophomore year	9
54-363	Dramaturgy 5 -Fall, Junior year	9
54-381	Special Topics: Feminist Theatre	6

Dramaturgy Electives (50 units minimum)

A minimum of **50** additional Dramaturgy units taken in the sophomore year or later must be approved by the Dramaturgy faculty area chair. A list of these selected courses must be filed in the BXA office.

Music Concentration

(108 units minimum)

Options available in the following areas: 1) Audio Recording & Production, 2) Composition, 2) Music Performance (instrumental, organ, piano, voice), 4) Sound Theory & Practice

Note: BXA music performance only considers internal transfer applicants in the spring semester for fall enrollment, unless currently enrolled in Music performance.

Audio Recording & Production Required Courses (8 courses, 49 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-101	Introduction to Music Technology	6
or 57-171	Introduction to Music Technology (self-paced)	
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-438	Multitrack Recording	9

Audio Recording & Production Electives (59 units minimum)

Choose **59** units from:

57-153	Harmony II	9
or 57-150	Basic Harmony II	
57-182	Solfege II	3
or 57-186	Advanced Solfege II	
10-301	Introduction to Machine Learning	12
15-104	Introduction to Computing for Creative Practice	10
15-213	Introduction to Computer Systems	12
15-322	Introduction to Computer Music	9
18-090	Twisted Signals: Multimedia Processing for the Arts	10
33-114	Physics of Musical Sound	9
54-166	Introduction to Sound Design for Theatre	6
54-666	Production Audio (section B)	4
57-161	Eurhythmics I	3
57-162	Eurhythmics II	3
57-344	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music	6
57-358	Introduction to Electronic Music (with instructor permission as space allows)	9
57-421	Exploded Ensemble	6
57-427	Advanced Seminar in Film Musicology	9
57-478	Survey of Historical Recording	6
57-622	Independent Study in Sound Recording Production	3
60-131	Foundations: Sculpture	10
85-385	Auditory Perception: Sense of Sound	9

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Audio Recording & Production concentration.

Composition Required Courses (13 courses, 85 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-161	Eurhythmics I (recommended co-requisite: 57-181)	3
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-49x	BXA Studio (4 semesters)	36
57-xxx	Major Ensemble (4 semesters)	24

Composition Electives (23 units minimum)

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Music Performance Required Courses (13 courses, 85 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-161	Eurhythmics I (recommended co-requisite: 57-181)	3
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-49x	BXA Studio (4 semesters)	36
57-xxx	Major Ensemble (4 semesters)	24

Music Performance Electives (23 units minimum)

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Sound Theory & Practice Required Courses (8 courses, 53 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-101	Introduction to Music Technology	6
or 57-171	Introduction to Music Technology (self-paced)	
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
18-090	Twisted Signals: Multimedia Processing for the Arts	10
57-421	Exploded Ensemble	6
57-911	Music Since 1945	9

Sound Theory & Practice Electives (55 units minimum)

Choose **55** units from:

57-153	Harmony II	9
or 57-150	Basic Harmony II	
57-182	Solfege II	3
or 57-186	Advanced Solfege II	
15-104	Introduction to Computing for Creative Practice	10
15-322	Introduction to Computer Music (prerequisite: 15-112)	9
33-114	Physics of Musical Sound	9
57-161	Eurhythmics I	3
57-162	Eurhythmics II	3
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-343	Music, Technology, and Culture	9
57-344	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music (prerequisite: 57-101 or 57-171)	6
57-358	Introduction to Electronic Music (with instructor permission as space allows)	9
57-438	Multitrack Recording	9
57-478	Survey of Historical Recording	6
57-616	Independent Study in Sound Studies	9

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Sound Theory & Practice concentration.

FREE ELECTIVES

(approximately 5-10 courses, 38-87 units minimum)

Take any Carnegie Mellon course. A maximum of 9 units of physical education and/or military science may be counted toward this requirement.

Bachelor of Humanities and Arts Degree Program

The Bachelor of Humanities and Arts (BHA) intercollege degree program combines the strengths of the College of Fine Arts (CFA) and the Dietrich College of Humanities and Social Sciences (DC). This degree is designed for academically and artistically talented students who want to develop their interest in the fine arts, while also pursuing studies in the humanities and social/behavioral sciences. Students choose their fine arts concentration from the following schools in CFA: Architecture, Art, Design, Drama or Music. Students choose their humanities and social sciences concentration from the subject areas offered by DC. The most important aspect of the BHA program is for students to blend their interests and to explore the connections between their chosen disciplines. The program also provides enough flexibility for students to broaden or deepen their concentrations and to explore other areas in which they may be interested.

The BHA curriculum has three main components: general education requirements, fine arts concentration requirements and humanities/social sciences concentration requirements. Students must complete an array of courses defined by their chosen concentrations. Each student's course of study is unique, based on their background and interests, and course availability in the respective colleges.

Students receive extensive advising support. The academic advisors in the BXA Intercollege Degree Programs are the primary advisors and liaisons between CFA and DC. Each student has two additional academic advisors: an advisor in the admitting school of CFA to guide their focus in the arts and an advisor in DC to guide their focus in the humanities or social/behavioral sciences.

BHA Curriculum

	Units
I. BHA General Education	**126**
II. DC Concentration	**81-107**
III. CFA Concentration	**108-130**
IV. Free Electives	**15-63**
Total BHA Degree Requirements	**378**

BHA General Education

(16 courses, 126 units minimum)

- Communication (1 course, 9 units, 76-101 required)
- Contextual Thinking (1 course, 9 units)
- Intercultural and Global Inquiry (1 course, 9 units)
- Humanities (1 course, 9 units)
- Data Analysis (1 course, 9 units, 36-200 required)
- Social Sciences (1 course, 9 units)
- Equity and Justice (1 course, 9 units)
- Math, Science, and Computation (2 courses, 18 units)
- Disciplinary Perspectives within CMU (1 course, 6 units)
- University Requirement (1 course, 3 units, 99-101 required)
- BXA Required Courses (5 courses, 36 units, 52-190, 52-291, 52-392, 52-401, 52-402)

Communication (1 courses, 9 units)

76-101	Interpretation and Argument -First-year	9
or 76-102	Advanced First Year Writing: Special Topics	
or 76-106 & 76-107 & 76-108	Writing about Literature, Art and Culture and Writing about Data and Writing about Public Problems	
All undergraduate students must complete the First-Year Writing requirement—the Department of English does not accept any Advanced Placement exemptions. This requirement can be completed in two different ways. Enroll in one of two full-semester courses 101 or 102 (by invitation only), 9 units, or enroll in two of three half-semester mini courses (back-to-back within a single semester) 106/107/108, 4.5 + 4.5 units. Course options and topics: www.cmu.edu/hss/english/first_year/index.html		

Contextual Thinking (1 course, 9 units)

A list of courses for this requirement can be found on the DC GenEd website (https://www.cmu.edu/dietrich/gened/fall-2021-and-beyond/course-options/).

Intercultural and Global Inquiry (1 course, 9 units minimum)

A list of courses for this requirement can be found on the DC GenEd website (https://www.cmu.edu/dietrich/gened/fall-2021-and-beyond/course-options/).

Humanities (1 course, 9 units minimum)

A list of courses for this requirement can be found on the DC GenEd website (https://www.cmu.edu/dietrich/gened/fall-2021-and-beyond/course-options/).

Data Analysis (1 course, 9 units minimum)

36-200	Reasoning with Data	9

Social Sciences (1 course, 9 units minimum)

A list of courses for this requirement can be found on the DC GenEd website (https://www.cmu.edu/dietrich/gened/fall-2021-and-beyond/course-options/).

Perspectives on Justice and Injustice (1 course, 9 units minimum)

A list of courses for this requirement can be found on the DC GenEd website (https://www.cmu.edu/dietrich/gened/fall-2021-and-beyond/course-options/).

Math, Science, and Computation (2 courses, 18 units minimum)

Choose two of three categories: Computational Thinking, Scientific Inquiry, Logic/Mathematical Reasoning. A list of courses for this requirement can be found on the DC GenEd website (https://www.cmu.edu/dietrich/gened/fall-2021-and-beyond/course-options/).

Disciplinary Perspectives within CMU (1 course, 6 units)

Choose one non-DC or CFA course; DC Arts courses excluded.

University Requirement (1 course, 3 units)

This foundational pass/no pass course is to be completed online in the first semester to develop core competency skills.

99-101	Core@CMU-Fall, First-year (section B; pass/no pass)	3

BXA Required Courses (5 courses, 36 units)

BXA-specific courses give students the opportunity to integrate their areas of concentration by focusing on interdisciplinary approaches and arts-based research techniques.

52-190	BXA Seminar I: Building the Wunderkammer - Spring, Freshman year (mini-3)	4.5
52-291	BXA Seminar II: Transferring Knowledge -Spring, Sophomore year (mini-4)	4.5
52-392	BXA Seminar III: Deconstructing Disciplines	9
52-401	BXA Seminar IV: Capstone Project Research	9
52-402	BXA Seminar V: Capstone Project Production	9

Dietrich College of Humanities and Social Sciences Concentrations

(number of courses vary, 81-107 units)

Curriculum for approved BHA DC concentration options are outlined below. BHA students declare a DC concentration based on existing DC programs, through consultation with their BXA advisor and the DC concentration advisors. A completed DC Concentration Declaration form must be approved by the concentration advisor and submitted to the BXA office, by spring mid-semester break of the student's sophomore year.

BHA students who are admitted as freshmen are undeclared until they have met with a concentration advisor and have submitted their signed Declaration form. BHA students who are admitted through internal transfer must have chosen a DC concentration at the time of their application (which serves as declaration). All BHA students wishing to change their DC concentration at any time following the initial declaration must meet with the advisor of their intended concentration area to complete a new Declaration form.

Behavioral Economics Concentration

(81 units minimum)

The new major of BE—the first of its kind among US undergraduate institutions—was designed to rigorously train students in the field of Behavioral Economics and to encourage them to critically consider its relevance to policy and organizations. The major emphasizes both theory and the practical promise of BE to solve problems of importance to policy makers and organizations through the largest undergraduate selection of BE courses of any university in the world. Towards this end, students will learn to collect original data, design field and laboratory experiments, analyze data and draw causal inferences, and develop interventions to improve economic outcomes and decisions. The core requirements include courses in Economics, Psychology, Behavioral Economics, and quantitative methods—including experimental design and econometrics. Students who complete the major will be well positioned to enter the private sector in a role involving data or people analytics, marketing, corporate strategy, or human resources, or to enter a wide range of graduate degree programs.

Quantitative Methods (3 courses, 27 units)

36-202	Methods for Statistics & Data Science	9
88-251	Empirical Research Methods	9
88-252	Causal Inference: from Data to Decisions	9
or 73-274	Econometrics I	

Economics Courses (2 courses, 18 units)

73-102	Principles of Microeconomics	9
or 73-104	Principles of Microeconomics Accelerated	
88-221	Markets, Democracy, and Public Policy	9
or 73-103	Principles of Macroeconomics	
or 73-155	Models, Math, and Markets	
or 73-230	Intermediate Microeconomics	
or 73-328	Health Economics	
or 73-347	Game Theory Applications for Economics and Business	
or 73-359	Benefit-Cost Analysis	
or 73-408	Law and Economics	
or 73-421	Emerging Markets	
or 73-427	Sustainability, Energy, and Environmental Economics	

Psychology Courses (2 courses, 18 units)

Students can elect to take 88-120 Reason, Passion and Cognition & 88-130 Behavioral Economics for Life or 88-120 Reason, Passion and Cognition & 88-302 Behavioral Decision Making. Students who have completed 88-302 Behavioral Decision Making or 88-360 Behavioral Economics cannot take 88-130 Behavioral Economics for Life.

88-120	Reason, Passion and Cognition -First-year or Sophomore year	9
88-130	Behavioral Economics for Life	9
or 88-302	Behavioral Decision Making	

Behavioral Economics Courses (2 courses, 18 units)

88-360	Behavioral Economics (prerequisite: 21-111)	9
88-367	Behavioral Economics & Field Experiments in Organizations	9
or 88-365	Behavioral Economics and Public Policy	

Chinese Studies Concentration

(81 units minimum)

A BHA concentration in Chinese Studies promotes not just language proficiency but also an understanding of Chinese culture. Students who arrive at Carnegie Mellon with previous language study and/or who have high Advanced Placement, an International Baccalaureate, a Cambridge GCE Advanced level or internal placement exam scores will be able to begin taking courses in the concentration earlier in their undergraduate program. In all cases, progress in the concentration will be accelerated by study abroad, which is recommended for all students.

Prerequisites

Intermediate-level proficiency in Chinese. This is equivalent to the completion of three courses (two at the 100-level and one at the 200-level) or may be demonstrated through CMU internal placement test scores.

Core Courses in Languages, Cultures, and Applied Linguistics (LCAL) (1 course, 9 units)

Complete one course.

82-239	Crazy Linguistically Rich Asian Languages	9
82-282	Interpreting Global Texts & Cultures	9
82-283	Language Diversity & Cultural Identity	9

Foundational Courses in Chinese Studies (5 courses, 45 units minimum)

82-232	Intermediate Chinese II	12
or 82-235	Fables, Legends and Stories from Ancient Chinese Civilization	
82-331	Reading Into a New China I: Population, Youth, Marriage, & Housing	9
82-332	Reading Into a New China II: Transportation, Education, Pop Culture, & Health	9
82-333	Introduction to Chinese Language and Culture	9
82-3–5xx One 300-, 400- or 500-level Chinese Language Content Course in Chinese		9

Chinese Studies Electives (3 courses, 27 units minimum)

In consultation with the concentration advisor, choose three additional courses, at least one of which must be taught in Chinese at the 300-, 400- or 500-level. Students may choose up to two Chinese culture courses taught in English. Students may substitute one relevant and related course from outside the program (i.e., another LCAL course) or from another department (e.g., History, CMIST, Philosophy, English).

Cognitive Neuroscience Concentration

(81 units minimum)

Cognitive neuroscience is a science concerned with discovering biological bases of psychological functions. It addresses questions of how behavior is produced by neural circuits of the brain and also how those neural circuits are in turn influenced by behavioral experiences. Students with a concentration in Cognitive Neuroscience are expected to learn about existing findings within the field and also to become proficient in how to conduct and analyze scientific investigations directed toward understanding the biological basis of behavior. This includes observing behavior, formulating hypotheses, designing experiments to test these hypotheses, running experiments, performing statistical analyses and writing reports.

Introductory and Survey Coursework (4 courses, 36 units)

03-121	Modern Biology	9
03-363	Systems Neuroscience	9
85-219	Foundations of Brain and Behavior	9
85-211	Cognitive Psychology	9
or 85-213	Human Information Processing and Artificial Intelligence	

Research Methods Training (2 course, 18 units)

36-309	Experimental Design for Behavioral & Social Sciences	9
or 85-309	Statistical Concepts and Methods for Behavioral and Social Science	
85-314	Cognitive Neuroscience Research Methods *	9

* *85-310 Research Methods in Cognitive Psychology may be substituted if necessary.*

Distribution Requirements (3 courses, 27 units)

Complete three courses with at least one from each category below.

Approaches to Cognitive Neuroscience:

15-386	Neural Computation	9
85-351	What is Attention?	9
85-407	How the Brain Makes Meaning	9
85-412	Cognitive Modeling	9
85-414	Cognitive Neuropsychology	9
85-417	Multilingual Minds and the Brain	9
85-419	Introduction to Parallel Distributed Processing	9

Cognitive Neuroscience Electives:

03-133	Neurobiology of Disease	9
03-362	Cellular Neuroscience	9
85-370	Perception	9
85-385	Auditory Perception: Sense of Sound	9
85-408	Visual Cognition	9
85-435	Biologically Intelligent Exploration	9
85-442	Health Psychology	9

Cognitive Science Concentration

(87 units minimum)

The field of cognitive science has grown out of increasingly active interaction among psychology, linguistics, artificial intelligence, philosophy, and neuroscience. All of these fields share the goal of understanding intelligence. By combining these diverse perspectives, students of cognitive science are able to understand cognition at a deep level. Because this concentration is administered by the Psychology Department, it focuses on human cognition and the experimental study of the human mind as illuminated by the techniques of the above disciplines.

Prerequisite Courses

15-112	Fundamentals of Programming and Computer Science	12
21-120	Differential and Integral Calculus	10-20
or 21-111 & 21-112	Calculus I and Calculus II	
21-127	Concepts of Mathematics	12

Statistics Course (1 course, 9 units)

36-309	Experimental Design for Behavioral & Social Sciences	9
or 85-309	Statistical Concepts and Methods for Behavioral and Social Science	

Computational/Cognitive Modeling Core (3 courses, 33 units)

Complete two of the following courses:

15-122	Principles of Imperative Computation	12
15-150	Principles of Functional Programming	12
15-251	Great Ideas in Theoretical Computer Science	12

Plus one of the following courses:

85-412	Cognitive Modeling	9
85-419	Introduction to Parallel Distributed Processing	9
85-435	Biologically Intelligent Exploration	9

Cognitive Psychology Core (4 courses, 36 units minimum)

85-211	Cognitive Psychology	9
or 85-213	Human Information Processing and Artificial Intelligence	
85-310	Research Methods in Cognitive Psychology	9
or 85-311	Research Methods: Meta-Analysis	
or 85-314	Cognitive Neuroscience Research Methods	

Plus two of the following (one of which must be 85-3xx or 85-4xx):

85-219	Foundations of Brain and Behavior	9
or 85-106	Animal Minds	
85-359	Introduction to Music Cognition Research	9
85-360	Origins of Intelligence	9
85-370	Perception	9
85-395	Applications of Cognitive Science	9
85-407	How the Brain Makes Meaning	9
85-408	Visual Cognition	9
85-414	Cognitive Neuropsychology	9
85-421	Language and Thought	9
80-310	Formal Logic	9
80-315	Logics for Knowledge and Belief	9
80-381	Meaning in Language	9
80-383	Language in Use	9
05-413	Human Factors	9
11-344	Machine Learning in Practice	12

Cognitive Science Elective (1 course, 9 units)

Choose one elective in consultation with your concentration advisor.

Creative Writing Concentration

(81 units minimum)

In the Creative Writing concentration, BHA students develop their talents in writing fiction, poetry and other imaginative forms. While studying with faculty members who are practicing poets and prose writers, students read widely in literature, explore the resources of their imaginations, sharpen their critical and verbal skills and develop a professional attitude toward their writing. The Creative Writing program is based on a conservatory model, made up of faculty and students who have an intense commitment to their work.

Students in the Creative Writing concentration are required to take two of the introductory genre writing courses, ideally in their sophomore year. Choices include Introduction to Writing Poetry (76-265), Introduction to Writing Fiction (76-260), Introduction to Screenwriting (76-269) and Introduction to Writing Nonfiction (76-261). In order to proceed into the upper level courses in the concentration (and in each of the genres), students must do well in these introductory courses (receive a grade of A or B). After completing the introductory genre writing courses, students take four workshops in fiction, poetry, screenwriting or nonfiction. At least two of the workshops must be taken in a single genre. Workshops may be taken more than once for credit. In the writing workshops, students develop their critical and verbal abilities through close writing and analysis of poems, stories and other literary forms. Their work is critiqued and evaluated by peers and the faculty.

Survey of Forms Courses (2 courses, 18 units)

76-260	Introduction to Writing Fiction	9
76-261	Intro to Writing Creative Nonfiction	9
76-265	Introduction to Writing Poetry	9
76-269	Introduction to Screenwriting	9

Note: A student must receive a grade of A or B in the Survey of Forms class in a specific genre in order to be eligible to enroll in a workshop of that genre. A student who receives a grade of C in a Survey of Forms course may enroll in a related workshop only with the permission of the workshop professor. A student who receives a D or R in Survey of Forms may not take a workshop in that genre.

Creative Writing Workshops (4 courses, 36 units)

Complete four Creative Writing workshops, at least two in a single genre. Workshops in all genres may be taken more than once for credit.

76-360	Literary Journalism Workshop	9
76-365	Beginning Poetry Workshop	9
76-460	Beginning Fiction Workshop	9
76-462	Advanced Fiction Workshop	9
76-464	Creative Nonfiction Workshop	9
76-465	Advanced Poetry Workshop	9
76-469	Screenwriting Workshop	9

English Electives (3 courses, 27 units)

Complete three courses (27 units minimum) from the English Department's offerings. Reading in Forms classes are recommended. Please consult the list of courses published each semester by the Department for current offerings. Students should discuss curriculum choices with the concentration advisor to determine the best electives for their focus in Creative Writing.

Cybersecurity & International Conflict

(81 units minimum)

The BHA concentration in cybersecurity and international conflict, offered by the Carnegie Mellon Institute for Strategy and Technology (CMIST), analyzes the past, present, and future role of cyber conflict and cybersecurity in international politics. Cyber attacks by nation-states and their proxies have an important impact upon conflict. The complexity and policy challenges of cyber-engagements is immense. This minor addresses the role of deterrence, dissuasion, and attribution in cyber conflict, while also studying the nuances of key components of modern warfare—from the security dilemma to escalation management.

Courses in this concentration focus on the existing gaps in our understanding of cybersecurity and international conflict, such as whether cyberspace is offense or defense dominant (or over time fluid between the two), and which factors are important in determining the answer to this. Other relevant questions include how nation-states, their primary adversaries, and a bevy of nonstate actors engage online and in the virtual and information environments. Accordingly, the minor exposes students to basic technology concepts, methods of attack and defense, potential strategy and goals for cyber-engagement, and response and forensics for cyber-engagements.

Alongside conventional methods of warfare, cybersecurity has rapidly developed into a centerpiece of a state's ability to project power. As the United States and other emerging cyber powers craft and implement doctrine in this domain, there is likely to be a rapid increase in activity, from efforts to disrupt the online activities of global terrorist networks, to cybersecurity offense and defense in the Russia-Ukraine war, to near daily raids on foreign networks designed to cripple states' cyberweapons before they can be deployed. In addition, the impact of cyberattacks on critical infrastructure, theft of intellectual property, pervasive identity theft, and hacking of sensitive databases have accumulated, gradually wearing down civilian networks and achieving strategic effects over time.

In the shifting landscape of cyber capabilities, how will laws, authorities, and policies keep pace? What are the implications and consequences of actions that may be considered "short of war" by some countries but "above the threshold" of conflict by others? Will a more aggressive defensive posture with respect to cybersecurity inadvertently increase the risk of conflict with states that sponsor malicious hacking groups? What is the proper balance between offense and defense in cybersecurity and how are cyber operations best integrated into a country's overall military strategy?

Unlike other kinds of conflicts, attribution of attacks presents significant challenges. Indeed, in many cases, it can be difficult to determine whether the attacker is a nation-state, a nonstate actor, a criminal gang, or a lone hacktivist. Investigators must combine technical and traditional methods to identify potentially responsible parties and to understand their intent. If the aggressor's identity cannot be confirmed, how can a counterattack be launched? Some attackers may seek to mount "false flag" attacks and deception, for example, that misdirect defenders to counter-attack in the wrong direction.

Additionally, what are appropriate responses to attacks made on civil infrastructure and private business operations, such as in the areas of financial services, transportation, energy, entertainment, and health care? In other words, what are the appropriate rules of engagement for national systems, infrastructural systems, businesses, and individuals? When, for example, is a counterattack or a "kinetic" response permissible?

These questions have major implications for the study of war and peace. Those who seek to start a war may be harder to find and their motives more difficult to discern. The cybersecurity and international conflict concentration tackles the social-scientific dimensions of cybersecurity with a focus on the implications of the cyber age for modern statecraft, warfare, elections (local, state, and national), and domestic and international politics.

Foundational Courses (2 courses, 18 units)

Students must complete two of the following courses:

84-104	Decision Processes in American Political Institutions	9
84-226	International Relations	9
84-275	Comparative Politics	9

Core Courses (3 courses, 24 units)

84-387	Remote Systems and the Cyber Domain in Conflict	9
84-388	Concepts of War and Cyber War	6
84-405	The Future of Warfare	9

Electives (4-5 courses, 39 units minimum)

At least two courses (18 units) must be taken from the CMIST and have an 84-number.

84-200	Security War Game Simulation	6
84-274	An Introduction to Technology and War	9
84-280	Popcorn and Politics: American Foreign Policy at the Movies	10
84-312	Terrorism in Sub-Saharan Africa	6
84-319	Civil-Military Relations	9
84-323	War and Peace in the Contemporary Middle East	9
84-325	Contemporary American Foreign Policy	9
84-328	Military Strategy and Doctrine	9
84-329	Asian Strategies	6
84-349	Digital Diplomacy: Cybersecurity Challenges and Global Governance	9
84-350	A Strategist's Introduction to Artificial Intelligence	9
84-363	Click. Hack. Rule: Understanding the Power & Peril of Cyber Conflict	9
84-365	The Politics of Fake News and Misinformation	9
84-370	Nuclear Security & Arms Control	9
84-372	Space and National Security	9
84-373	Emerging Technologies and International Law	9
84-380	US Grand Strategy	9
84-383	Cyber Policy as National Policy	6
84-386	The Privatization of Force	9

84-389	Terrorism and Insurgency	9
84-390	Social Media, Technology, and Conflict	9
16-735	Ethics and Robotics	12
17-200	Ethics and Policy Issues in Computing	9
17-303	Cryptocurrencies, Blockchains and Applications	9
17-331	Information Security, Privacy, and Policy	12
17-333	Privacy Policy, Law, and Technology	9
17-334	Usable Privacy and Security	9
17-702	Current Topics in Privacy Seminar	3
79-301	History of Surveillance: From the Plantation to Data Capitalism	6
79-302	Killer Robots? The Ethics, Law, and Politics of Drones and A.I. in War	9
80-249	AI, Society, and Humanity	9
95-444	Cybersecurity Policy and Governance II	12

Decision Science Concentration

(84 units minimum)

Decision Science is grounded in theories and methods drawn from psychology, economics, philosophy, statistics, and management science. Courses in the BHA concentration in Decision Science cover the three aspects of decision science: (a) normative analysis, creating formal models of rational choice; (b) descriptive research, studying how cognitive, emotional, social, and institutional factors affect judgment and choice, and (c) prescriptive interventions, seeking to improve judgment and decision making. In addition to gaining a broad education in the principles of judgment and decision making, students with a concentration in Decision Science gain broadly applicable skills in research design and analysis. They also have the chance to think about and discuss decision making in many different areas.

Disciplinary Perspectives (5 courses, 48 units)

73-102	Principles of Microeconomics	9
or 73-104	Principles of Microeconomics Accelerated	
85-102	Introduction to Psychology	9
88-120	Reason, Passion and Cognition -First-year or Sophomore year	9
88-223	Decision Analysis	12
88-302	Behavioral Decision Making	9

Research Methods (2 courses, 18 units)

36-202	Methods for Statistics & Data Science	9
or 36-309	Experimental Design for Behavioral & Social Sciences	
or 85-309	Statistical Concepts and Methods for Behavioral and Social Science	
88-251	Empirical Research Methods	9

Electives (2 course, 18 units minimum)

Complete two courses (at least 18 units) from the following category of courses. Note that not all elective courses are offered every year.

Biological and Behavioral Aspects of Decision Making:

88-150	Managing Decisions	9
88-221	Markets, Democracy, and Public Policy	9
88-230	Human Intelligence and Human Stupidity	9
88-231	Thinking in Person vs. Thinking Online	9
88-252	Causal Inference: from Data to Decisions	9
88-234	Negotiation: International Focus	9
88-235	Negotiation: Strategies and Behavioral Insights	9
88-255	Strategic Decision Making	9
88-261	Health Policy and Decision Making	9
88-262	Medical Decision Making	9
88-275	Bubbles: Data Science for Human Minds	9
88-285	Deconstructing and Dismantling Discrimination	9
88-290	Confessions, Lies, and Gossip	9
88-300	Programming and Data Analysis for Social Scientists	9
88-312	Decision Models and Games	9
88-342	The Neuroscience of Decision Making	9
88-344	Systems Analysis: Environmental Policy	9
88-360	Behavioral Economics	9
88-365	Behavioral Economics and Public Policy	9
88-366	Behavioral Economics of Poverty and Development	9
88-367	Behavioral Economics & Field Experiments in Organizations	9
88-372	Social and Emotional Brain	9
88-379	Data-Driven Decision Analysis	9
88-451/452	Policy Analysis Senior Project	12
88-454	Decision Science Capstone	9

Economics Concentration

(84 units minimum)

The BHA concentration in Economics provides a solid understanding of economic theory and quantitative economic analysis. The core disciplinary sequences in economic theory and quantitative analysis are combined with calculus and data analysis to provide students with knowledge and skills that allow for creative problem-solving. Students pursuing the BHA concentration in Economics will hold a Dietrich College affiliation.

Mathematics Prerequisites

These courses are not counted as part of your DC Concentration. It may be used to satisfy general education or free elective requirements.

21-120	Differential and Integral Calculus	10
21-256	Multivariate Analysis	9

Economic Theory Requirements (4 courses, 36 units)

73-102	Principles of Microeconomics *	9
or 73-104	Principles of Microeconomics Accelerated	
73-103	Principles of Macroeconomics	9
73-230	Intermediate Microeconomics	9
73-240	Intermediate Macroeconomics	9

* *Students who place out of* 73-102 *based on the economics placement exam will receive a prereq waiver for* 73-102 *and are waived from taking* 73-102.

Quantitative Analysis Requirements (2 courses, 18 units)

These courses require 36-200 Reasoning with Data as a pre-requisite. 36-200 also fulfills a general education Data Analysis requirement.

73-265	Economics and Data Science	9
73-274	Econometrics I	9

Advanced Economics Electives (2 courses, 18 units)

Students must take two advanced elective courses. Advanced elective courses are those numbered 73-300 through 73-495, as well as courses designated by the program offered by other departments/programs. Additionally, students may work with their economics advisor to structure alternative sets of courses to meet these requirements based on their particular interests, subject to course availability.

Senior Work (1 course, 12 units)

73-497	Senior Project	12

Environmental & Sustainability Studies **Concentration**

(93 units minimum)

The BHA concentration in Environmental & Sustainability Studies (ESS) focuses on human-environment interactions from a multitude of disciplinary perspectives. The curriculum draws on the expertise of faculty across several Carnegie Mellon colleges in order to provide students with the interdisciplinary background and skills necessary to understand environmental problems and the means to mitigate them. The curriculum is designed to help students apply social and scientific perspectives to environmental problems; to distinguish among scientific methods for evaluating environmental problems; to identify and assess sources of environmental data; and to identify environmental justice issues within the context of proposed policy solutions.

Core Courses (3 course, 27 units)

24/09-291	Environmental Systems on a Changing Planet	9
66-236	Introduction to Environmental Ideas	9
66-506	Senior Capstone (Interdisciplinary Research: Capstone in ESS)	9

Earth and Environmental Science (1 course, 9 units)

Choose one course from the list below.

03-128	Biology for Life Special Topics (Section S, Tropical Ecology)	9
03-140	Ecology and Environmental Science	9
33-115	Physics for Future Presidents	9

Global Course (1 course, 3 units)

99-xxx	Each semester, a new course is offered on Global themes, in partnership with University of Pittsburgh's Global Studies Center.	3

Political Economy (1 course, 9 units minimum)

Choose one course from the list below.

19-101	Introduction to Engineering and Public Policy	12
79-300	Controversial Topics in the History of American Public Policy	9
84-110	The Economics of Politics, Policy, and Technology	9
84-226	International Relations	9
84-325	Contemporary American Foreign Policy	9
88-344	Systems Analysis: Environmental Policy	9

Electives (5 courses, 45 units minimum)

Choose three DC Electives and two MCS/ENG Electives in consultation with the concentration advisor.

DC Electives:

76-241	Introduction to Gender Studies	9
76-291	Getting Heard/Making a Difference	9
76-354	Watchdog Journalism	9
76-395	Science Writing *	9
76-450	Law, Culture, and the Humanities	9
79-201	Introduction to Anthropology	9
79-275	Introduction to Global Studies	9
79-278	How (Not) to Change the World	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-297	Technology and Work	9
79-331	Body Politics: Women and Health in America	9
79-372	The Rise and Fall of Pittsburgh Steel	6
79-377	Food, Culture, and Power: A History of Eating	9
79-379	Extreme Ethnography	9
79-383	The History of Capitalism	9
80-135	Introduction to Political Philosophy	9
80-244	Environmental Ethics	9
84-110	The Economics of Politics, Policy, and Technology	9
84-275	Comparative Politics	9
84-325	Contemporary American Foreign Policy	9
85-241	Social Psychology	9

MCS/ENG Electives:

12-201	Geology	9
19-101	Introduction to Engineering and Public Policy	12
19-425	Sustainable Energy for the Developing World	9
27-505	Exploration of Everyday Materials	9
03-140	Ecology and Environmental Science	9

** Additional prerequisite*

Ethics, History, & Public Policy Concentration

(81 units minimum)

The BHA concentration in Ethics, History, & Public Policy (EHPP) prepares students to be leaders is a vital goal of colleges and universities in every democratic society. The intellectual challenges facing public and private sector leaders have expanded dramatically since the pioneering EHPP program began in 1996, but the need remains as great as ever for broadly educated, ethically sensitive, and technically skilled leaders.

EHPP prepares students to demonstrate sophistication and flexibility in their command of interdisciplinary knowledge; deep historical understanding of how modern-day policy problems have emerged and evolved; and clear, rational criteria for ethical and socially just decision making. The curriculum provides students with a strong humanistic foundation for developing such high-level, historically grounded, and ethically attuned leadership capacities. It also offers ample room for specialization in a wide range of policy areas in which the History and Philosophy departments have special expertise, e.g., medicine and public health, criminal justice, environment, technology, artificial intelligence (AI), gender, civil rights, immigration, and education.

Foundation Courses in History and Philosophy (2 courses, 18 units)

Choose one of the following two courses:

79-189	Democracy and History: Thinking Beyond the Self	9
79-248	U.S. Constitution & the Presidency	9

Choose one of the following two courses:

80-130	Introduction to Ethics	9
80-330	Ethical Theory	9

Ethics and Policy Core (3 courses, 27 units)

Choose three of the courses below:
No more than one course may be taken at the 100 level and at least one course must be taken at the 300 level or above.

80-135	Introduction to Political Philosophy	9
80-136	Social Structure, Public Policy & Ethics	9
80-208	Critical Thinking	9
80-221	Philosophy of Social Science	9
80-234	Race, Gender, and Justice	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-249	AI, Society, and Humanity	9
80-305	Game Theory	9
80-306	Decision Theory	9
80-324	Philosophy of Economics	9
80-330	Ethical Theory	9
80-335	Social and Political Philosophy	9
80-336	Philosophy of Law	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9

History and Policy Core (3 courses, 27 units)

Choose three of the courses below:

79-175	Moneyball Nation: Data in American Life	9
79-204	American Environmental History	9
79-212	Jim Crow America	9
79-215	Environmental Justice from Conservation to Climate Change	9
79-234	Technology and Society	9
79-242	African American History: Reconstruction to the Present	9
79-248	U.S. Constitution & the Presidency	9
79-250	Voting Rights: An Introduction	9
79-278	How (Not) to Change the World	9
79-300	Controversial Topics in the History of American Public Policy	9
79-320	Women, Politics, and Protest	9
79-321	Documenting Human Rights	9
79-330	Medicine and Society: Health, Healers, and Hospitals	9
79-343	Education, Democracy, and Civil Rights	9
79-360	Crime, Policing, and the Law: Historical and Contemporary Perspectives	9
79-370	Technology in the United States	9
79-380	Hostile Environments: The Politics of Pollution in Global Perspective	9

Foundation Courses in Law and Social Science (1 course, 9 units minimum)

Choose one of the courses below:

17-200	Ethics and Policy Issues in Computing	9
19-101	Introduction to Engineering and Public Policy	12
70-332	Business, Society and Ethics	9
73-102	Principles of Microeconomics	9

73-103	Principles of Macroeconomics	9
84-104	Decision Processes in American Political Institutions	9
84-110	The Economics of Politics, Policy, and Technology	9
84-352	Representation and Voting Rights	9
84-393	Legislative Decision Making: US Congress	9
84-402	Judicial Politics and Behavior	9
88-281	Topics in Law: 1st Amendment	9
88-284	Topics of Law: The Bill of Rights	9

Film & Visual Media Concentration

(81 units minimum)

The BHA concentration in Film & Visual Media trains students through a combination of coursework in visual media, film history and analysis, screenwriting, and production of film and other visual media. This concentration offers a comprehensive education in film and visual media, from theoretical framing and historical-cultural contextualization to training skills in both creating and analyzing film, and developing a complex blend of creative, professional and technical competencies. CMU's Department of English is an ideal home for the Film & Visual Media concentration due to the department's combination of creative writers, film and media studies scholars, film makers, digital humanities and visual communication researchers.

Introductory Courses (2 courses, 18 units)

76-239	Introduction to Film Studies	9
76-259	Film History	9

Production Course (1 course, 9 units)

76-292	Introduction to Film Production	9

Screenwriting Course (1 course, 9 units)

76-269	Introduction to Screenwriting	9

Topics in Film & Visual Media Studies (2 courses, 18 units)

Options include but are not limited to:

76/82-278	Japanese Film and Literature: The Art of Storytelling	9
76-312/79-308	Crime and Justice in American Film	9
76-339	Topics in Film and Media (Can be taken more than once.)	9
76-353	Transnational Feminisms: Fiction and Film	9
76-367/79-306	Fact Into Film: Translating History into Cinema	9
76-401	Hollywood vs. the World	9
76-439	Seminar in Film and Media Studies	9
76-448	Shakespeare on Film	9
76-454	Rise of the Blockbuster	9
79-225	West African History in Film	9
79-319	India Through Film	6
79-326	Shall We Dance? Culture, Politics, and Movement in the 20th Century	6
82-215	Arab Culture Through Dialogues, Film, and Literature	9
82-268	Introduction to Italian Film	9
82-284	Multicultural Pittsburgh: VR Storytelling	6

Courses in Film Production, Screenwriting, Digital Media, Literature & Culture, and/or Film & Visual Media Studies (3 courses, 27 units)

Students may take an additional three Dietrich College courses for a minimum of 27 units of courses offered in the categories listed above. Because there are dozens of options available, including many of the courses listed above, please consult with the Department of concentration advisor for guidance. Recommended courses include 76-310 Advanced Studies in Film and Media, 76-323 Text to Screen, and 76-374 Mediated Narrative.

French & Francophone Studies Concentration

(81 units minimum)

A BHA concentration in French & Francophone Studies promotes not just language proficiency but also an understanding of French and francophone cultures. Students who arrive at Carnegie Mellon with previous language study and/or who have high Advanced Placement, an International Baccalaureate, a Cambridge GCE Advanced level or internal placement exam scores will be able to begin taking courses in the concentration earlier in their undergraduate program. In all cases, progress in the concentration will be accelerated by study abroad, which is recommended for all students.

Prerequisites

Elementary-level proficiency in French. This is equivalent to the completion of two courses (two at the 100-level) or may be demonstrated through CMU internal placement test scores.

Core Courses in Languages, Cultures & Applied Linguistics (LCAL) (2 courses, 18 units)

82-282	Interpreting Global Texts & Cultures	9
82-283	Language Diversity & Cultural Identity	9

Foundational Courses in French & Francophone Studies (5 courses, 45 units)

82-201	Intermediate French I	9
or 82-203	Intermediate French I Online	
82-202	Intermediate French II	9
or 82-204	Intermediate French II Online	
82-303	French & Francophone Cultures (may be repeated)	9
82-304	French & Francophone Sociolinguistics (may be repeated)	9

French & Francophone Studies Electives (2 courses, 18 units)

In consultation with the concentration advisor, choose two additional courses related to French & Francophone Studies.

German Studies Concentration

(81 units minimum)

A BHA concentration in German Studies promotes not just language proficiency but also an understanding of German culture. Students who arrive at Carnegie Mellon with previous language study and/or who have high Advanced Placement, an International Baccalaureate, a Cambridge GCE Advanced level or internal placement exam scores will be able to begin taking courses in the concentration earlier in their undergraduate program. In all cases, progress in the concentration will be accelerated by study abroad, which is recommended for all students.

Prerequisites

Elementary-level proficiency in German. This is equivalent to the completion of two courses (at the 100-level) or may be demonstrated through CMU internal placement test scores.

Core Courses in Languages, Cultures & Applied Linguistics (LCAL) (1 course, 9 units)

82-28x	Choose one LCAL course	9

Foundational Courses in German Studies (5 courses, 45 units)

82-221	Intermediate German I	9
82-222	Intermediate German II	9
82-320	Contemporary Society in Germany, Austria and Switzerland	9
82-323	Germany, Austria and Switzerland in the 20th Century	9
82-425	Topics in German Literature and Culture	9
or 82-426	Topics in German Literature and Culture	

German Studies and Interdisciplinary Electives (3 courses, 27 units)

In consultation with the concentration advisor, choose three additional courses taught in either German or English, for example, additional 400-level courses in German Studies or a departmental elective.

Global Studies Concentration

(81 units minimum)

The BHA concentration in Global Studies is designed for students interested in humanistic approaches to understanding past and present processes of globalization. Participating faculty in the departments of History, Languages, Cultures, and Applied Linguistics and English conduct research in Africa, Asia, Europe, Latin America, the Middle East and the Pacific. The rigorous yet flexible Global Studies curriculum combines anthropology, history, literary and cultural studies, and advanced language training in order to help students make sense of complex interactions among global processes, regional and local cultures, and societal structures. BHA concentration students in Global Studies develop a broad understanding of their prospects and responsibilities as citizens of the world confronting challenging contemporary problems.

There are two required courses for the concentration: Introduction to Global Studies (79-275) and Global Studies Research Seminar (79-400). Students also choose among several courses focused on theory, research methods, transnational histories, and regional/national histories and cultures.

In addition to coursework at Carnegie Mellon, BHA students with a concentration in Global Studies are encouraged to incorporate a semester of study abroad into their course of study in order to immerse themselves in society different from their own with unfamiliar cultural practices, language and history.

Students should consult frequently with the BHA advisor and the Global Studies concentration advisor who will help students to craft a coherent course of study on specific topics and/or regions that may lead to the capstone research project (79-400 Global Studies Research Seminar), the BXA capstone project (52-401 and 52-402) or a Dietrich College senior honors thesis (https://www.cmu.edu/dietrich/students/undergraduate/programs/senior-honors/). The concentration advisor will also work with students to connect their academic interests and their participation in student organizations and/or organizations based in Pittsburgh with transnational reach.

Global Studies Introductory and Capstone Courses (2 courses, 21 units)

Students must earn a final grade of "C" or better for these courses to count toward the concentration.

79-275	Introduction to Global Studies	9
79-400	Global Studies Research Seminar	12

Language Proficiency Requirement

Demonstrating intermediate to advanced level proficiency in a language other than English is a crucial component of the major in Global Studies. Normally this requirement can be satisfied by successfully completing a course conducted in the second language at the 300-level or above for French, German, Italian, or Spanish, or the fourth semester (Intermediate II) level or above for Arabic, Chinese, Japanese, or Russian. Comparable proficiency for other languages can be considered. Additional advanced cultural, historical, and literary study in the second language is strongly recommended. Courses in a language other than English may also be counted as Global Studies transnational, global, or regional courses or Global Studies electives as appropriate.

If students already know a language at an advanced level, they will take a test to certify those language skills. If they pass the test, they will need to take at least two semesters of language study, focused on a language different from the one they were tested on.

Studying abroad for one semester, in a foreign country whose language is not English, is an alternative way to fulfill the language requirement.

Please see the Languages, Cultures, and Applied Linguistics section of the schedule of classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/).

Theoretical and Topical Core Courses (2 courses, 18 units)

To gain a solid foundation in the theories, methods, and analytical topics underpinning the concentration in Global Studies, students select 18 units (typically two courses) from the core courses listed below. Students must earn a final grade of "C" or better in these courses to fulfill the theoretical and topical core course requirement.

79-201	Introduction to Anthropology	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-278	How (Not) to Change the World	9
79-280	Coffee and Capitalism	9
79-289	Animal Planet: An Environmental History of People and Animals	9
79-314	How Do We Remember? The Politics and Cultures of Memory	9
79-315	The Politics of Water in Global Perspective	9
79-317	Art, Anthropology, and Empire	9
79-318	Sustainable Social Change: History and Practice	9
79-377	Food, Culture, and Power: A History of Eating	9
79-379	Extreme Ethnography	9
79-380	Hostile Environments: The Politics of Pollution in Global Perspective	9
79-383	The History of Capitalism	9

Transnational, Global, and Regional Courses (3 courses, 27 units)

To gain insight into how complex transnational and global processes shape and are affected by local, national and regional dynamics, students will select 27 units (typically three courses) from any subcategories below.

Transnational and Global Courses:

76-337	Intersectional Feminism	9
76-353	Transnational Feminisms: Fiction and Film	9
76-384	Race, Nation, and the Enemy	9
76-440	Postcolonial Theory: Diaspora and Transnationalism	9
79-149	Ancient Rome: What Have the Romans Ever Done for Us?	9
79-237	Comparative Slavery	9
79-270	Anti-Semitism Then and Now: Perspectives from the Middle Ages to the Present	9
79-273	Jews and Muslims in History	9
79-276	Beyond the Border	9
79-280	Coffee and Capitalism	9
79-282	Europe and the World Since 1800	9
79-283	Hungry World: Food and Famine in Global Perspective	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-313	"Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration	6
79-333	African Americans, Race, and the Fight for Reparations	9
79-350	Early Christianity	9
79-368	Un-natural Disasters: Societies and Environmental Hazards in Global Perspective	6
79-385	Out of Africa: The Making of the African Diaspora	9
79-510	Global Studies Guided Reading	3
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9
82-283	Language Diversity & Cultural Identity	9
82-304	French & Francophone Sociolinguistics	9
82-345	Using Spanish in Social Contexts	9
84-226	International Relations	9
84-322	Nonviolent Conflict and Revolution	9
84-370	Nuclear Security & Arms Control	9
84-389	Terrorism and Insurgency	9

Regional Courses:

Africa		
79-225	West African History in Film	9
79-226	African History: Earliest Times to 1780	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-290	The Slave Passage: From West Africa to the Americas	9

Eastern and Southern Asia and the Pacific		
79-207	Asian American History through the Novel	9
79-210	Identity, Ethnicity, and Place in Modern China	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-264	Tibet and China: History and Propaganda	9
88-411	Rise of the Asian Economies	9

Europe		
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-203	The Other Europe: The Habsburgs, Communism, & Central/Eastern Europe, 1740-1990	9
79-205	20th Century Europe	9
79-208	Witchcraft and Witch-Hunting	9
79-268	World War I: The Twentieth Century's First Catastrophe	9
79-270	Anti-Semitism Then and Now: Perspectives from the Middle Ages to the Present	9

79-272	Coexistence and Conflict: Muslims, Christians and Jews in Spain and Portugal	9
82-320	Contemporary Society in Germany, Austria and Switzerland	9
82-415	Topics in French and Francophone Studies	9
82-441	Studies in Peninsular Literature and Culture	9

The Middle East

79-229	The Origins of the Palestinian-Israeli Conflict, 1880-1948	9
79-230	The Arab-Israeli Conflict and Peace Process Through 1948 to Present	9
82-215	Arab Culture Through Dialogues, Film, and Literature	9
84-323	War and Peace in the Contemporary Middle East	9

The Americas

79-223	Mexico: From the Aztec Empire to the Drug War	9
82-245	New Directions in Hispanic Studies	9
82-343	Latin America Language and Culture	9
82-451	Studies in Latin American Literature and Culture	9
82-455	Topics in Hispanic Studies	9
82-456	Topics in Hispanic Studies	9

Electives (2 courses, 15 units minimum)

Students are required to take an additional 15 units (typically two courses) of electives, selected from one or both of the subcategories below. "Theoretical and Topical Core Courses" and "Transnational, Global, and Regional Courses" listed above that are not used to fulfill those requirements may be counted as electives in addition to the courses listed below.

Global Studies offers students the opportunity to gain credit for a 9-unit elective while gaining first-hand experience interning with Pittsburgh-based organizations that work across borders. 79-506 Global Studies Internship is offered every semester and students should register for the course after consulting with the concentration advisor. The concentration advisor will assist students with matching their interests to local organizations and identifying an on-site supervisor available to collaborate in the ongoing and final evaluation of the student's work.

Thematic Courses:

57-306	World Music	9
70-365	International Trade and International Law	9
76-241	Introduction to Gender Studies	9
76-386	Language & Culture	9
76-450	Law, Culture, and the Humanities	9
76-468	Space and Mobilities	9
79-101	Making History: How to Think About the Past (and Present)	9
79-204	American Environmental History	9
79-281	Introduction to Religion	9
79-316	Photography, the First 100 Years, 1839-1939	9
79-324	#MeToo: Naming and Resisting Gender Violence	6
79-330	Medicine and Society: Health, Healers, and Hospitals	9
79-343	Education, Democracy, and Civil Rights	9
80-244	Environmental Ethics	9
80-335	Social and Political Philosophy	9
82-215	Arab Culture Through Dialogues, Film, and Literature	9
82-541	Special Topics in Hispanic Studies	Var.
84-275	Comparative Politics	9
84-310	Policy in a Global Economy 1: International Trade and Trade Policy	6
84-318	Politics of Developing Nations	9
84-362	Diplomacy and Statecraft	9
88-234	Negotiation: International Focus	9

Nation-based Courses:

79-216	Genghis Khan and the Mongol Empire	3
79-256	Sex, Guns, Rock, and Skinheads: Youth Rebellion in Europe, 1960-1990	9
79-257	Germany and the Second World War	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-263	Mao and the Chinese Cultural Revolution	9
79-265	Russian History: Game of Thrones	9
79-266	Russian History and Revolutionary Socialism	9
79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-269	Russian History: From Socialism to Capitalism	9
79-309	The Chinese Revolution Through Film (1949-2000)	9
79-319	India Through Film	6
79-320	Women, Politics, and Protest	9
79-322	Stalin and the Great Terror	9
79-326	Shall We Dance? Culture, Politics, and Movement in the 20th Century	6
79-331	Body Politics: Women and Health in America	9
82-253	Korean Culture Through Film	9
82-254	World of Korea, Then and Now	9
82-273	Introduction to Japanese Language and Culture	9
82-278	Japanese Film and Literature: The Art of Storytelling	9
82-293	Russian Cinema: From the Bolshevik Revolution to Putin's Russia	9
82-294	19th Century Russian Masterpieces	9
82-295	20th Century Russian Masterpieces	Var.
82-303	French & Francophone Cultures	9
82-305	French in its Social Contexts	9
82-333	Introduction to Chinese Language and Culture	Var.
82-342	Spain: Language and Culture	9
82-344	U.S. Latine Cultures	9
82-361	Italian Language and Culture I	9
82-420	The Crucible of Modernity:Vienna 1900	9
82-425	Topics in German Literature and Culture	9
82-427	Nazi and Resistance Culture	9
82-428	History of German Film	9
82-433	Topics in Contemporary Culture of China	9
82-434	Studies in Chinese Traditions	9
82-440	Studies in Chinese Literature & Culture	9
82-473	Topics in Japanese Studies	9

Hispanic Studies Concentration

(81 units minimum)

A BHA concentration in Hispanic Studies promotes not just language proficiency but also an understanding of its varied cultures. Students who arrive at Carnegie Mellon with previous language study and/or who have high Advanced Placement, an International Baccalaureate, a Cambridge GCE Advanced level or internal placement exam scores will be able to begin taking courses in the concentration earlier in their undergraduate program. In all cases, progress in the concentration will be accelerated by study abroad, which is recommended for all students.

Prerequisites

Intermediate-level proficiency in Spanish. This is equivalent to the completion of four courses (two at the 100-level and two at the 200-level) or may be demonstrated through CMU internal placement test scores.

Core Courses in Languages, Cultures and Applied Linguistics (LCAL) (1 course, 9 units)

Complete one course.

82-280	Billingual & Bicultural Experiences in the US	9
82-282	Interpreting Global Texts & Cultures	9
82-283	Language Diversity & Cultural Identity	9
82-482	Introduction to Translation	9

Foundational Courses in Hispanic Studies (3 courses, 27 units)

Complete two courses.

82-342	Spain: Language and Culture	9
82-343	Latin America Language and Culture	9
82-344	U.S. Latine Cultures	9

Complete required course.

82-345	Using Spanish in Social Contexts	9

Hispanic Studies Electives (5 courses, 45 units)

In consultation with the concentration advisor, choose five additional courses taught in Spanish at the 400-level or above. Students may substitute one relevant and related course from outside the program (i.e., another LCAL course) or from another department (e.g., History, CMIST, Philosophy, English).

Humanities Analytics Concentration

(81 units minimum)

The human experience that is traditionally at the core of a humanities education is being dramatically transformed by the emergence of big data, digital platforms, computational thinking, and digital connectivity. Spurred by such developments, the concentration in Humanities Analytics (HumAn), offered by the Department of English, trains students in the processes involved in analyzing, digitizing, quantifying and visualizing different types of humanities and cultural phenomena, including printed books, manuscripts, historical records, art, music and film. The HumAn concentration trains students to work with cultural objects (like texts, film, historical records, etc.) but also to turn words and images into data; to move from one cultural object (like a Victorian novel, for instance) to a corpus consisting of tens of thousands of other novels published in the same period, and to combine close reading with distant reading (aggregating and analyzing massive amounts of data) for maximum insight and accuracy.

Students will develop a broad technical understanding of state-of-the-art computer-assisted methods for humanistic study, such as: social network analysis, text analysis and data mining, topic modeling, classification techniques and visualization. Students will also investigate the histories and historical contexts of such methods, learning to consider their applicability in specific domains. Finally, students will learn to turn a critical eye on the corpora and infrastructures that increasingly underpin humanistic research.

Required Courses (5 courses, 45 units)

76-275	Introduction to Critical Writing	9
76-380	Methods in Humanities Analytics	9

Three core courses from the following list:

76-314	Data Stories	9
76-388	Coding for Humanists	9
76-425	Rhetoric, Science, and the Public Sphere	9
76-429	Introduction to Digital Humanities	9
88-275	Bubbles: Data Science for Human Minds	9
88-300	Programming and Data Analysis for Social Scientists	9

Electives (4 courses, 36 units minimum)

Choose four courses from the following categories. One course must come from List A, two from List B, and the fourth in consultation with your Humanities Analytics advisor.

List A: One elective course relevant to digital and analytics methods (at least 9 units):

05-391	Designing Human Centered Software	12
05-434/11-344	Machine Learning in Practice	12
11-411	Natural Language Processing	12
11-441/741	Machine Learning with Graphs (Course is very mathematical, and is therefore appropriate only to students with such a preparation.)	9
15-104	Introduction to Computing for Creative Practice	10
15-110	Principles of Computing	10
15-112	Fundamentals of Programming and Computer Science	12
16-223	IDeATe Portal: Creative Kinetic Systems	10
16-385	Computer Vision	12
17-340	Green Computing	9
17-450	Crafting Software	12
17-562	Law of Computer Technology	9
18-090	Twisted Signals: Multimedia Processing for the Arts	10
36-202	Methods for Statistics & Data Science	9
36-204	Discovering the Data Universe	3
36-226	Introduction to Statistical Inference	9
36-311	Statistical Analysis of Networks	9
36-315	Statistical Graphics and Visualization	9
36-350	Statistical Computing	9
36-462	Special Topics: Statistical Machine Learning	9
48-095	Spatial Concepts for Non-Architecture Majors	10
48-120	Digital Media I	6
51-229	Digital Photographic Imaging	9
53-451	Research Issues in Game Development: Designing for XR	12
60/62-142	Digital Photography I	10
62-150	IDeATe Portal: Introduction to Media Synthesis and Analysis	10

List B: Two elective courses relevant to broad humanities expertise (at least 18 units):

76-210	Banned Books	9
76-245	Shakespeare: Tragedies & Histories	9
76-247	Shakespeare: Comedies and Romances	9
76-325	Intertextuality	9
76-339	Topics in Film and Media	9
76-373	Argument	9
76-476	Rhetoric of Science	9
79-175	Moneyball Nation: Data in American Life	9
79-200	Introduction to Historical Research & Writing	9
79-234	Technology and Society	9
80-180	Nature of Language: An Introduction to Linguistics	9
80-280	Linguistic Analysis	9
80-381	Meaning in Language	9
80-383	Language in Use	9
82-282	Interpreting Global Texts & Cultures	9
82-283	Language Diversity & Cultural Identity	9
82-383	Second Language Acquisition: Theories and Research	9
82-480	Translation Technologies	9

Note: Additional courses not on List A or List B may also be approved as electives; new courses are added every semester so please speak with Humanities Analytics advisor.

Information Systems Concentration

(107 units minimum)

Did you enjoy computer science or more technical courses in high school, but are mostly interested in the practical and social applications of technology? Do you have a passion for business and want to use advanced technology to change how companies work? Do you want to learn how data and technology can be harnessed for social good?

The BHA concentration in Information Systems combines aspects of computer science, information technology, and business management to provide you with an uncommonly well-rounded portfolio. You will be uniquely positioned for an impactful career in an increasingly digitized and connected world and able to adapt to rapid evolution across industries.

In addition to building a solid foundation in computing, communications, and software development, you will also study social sciences and organizational theory to develop "big picture" critical thinking and understand the human impacts of technological change. This blend prepares you to take a leading role in our digital future.

Students must earn a final grade of "C" or better for these courses to count toward the concentration.

Technical Core (3 courses, 31 units minimum)

Information Systems requires completion of prerequisite courses in mathematics and computer science. All prerequisites must be successfully completed prior to the start of fall semester, junior year. Two Technical Core courses may double-count in the BHA General Education Math, Science, and Computation category.

15-112	Fundamentals of Programming and Computer Science	12
15-121	Introduction to Data Structures	10
or 15-122	Principles of Imperative Computation	

Choose one:

21-112	Calculus II	10
21-120	Differential and Integral Calculus	10
21-127	Concepts of Mathematics	12
21-240	Matrix Algebra with Applications	10
80-210	Logic and Proofs	9

Information Systems Professional Core (8 courses, 76 units)

67-200	Information Systems Research Colloquium -Fall	1
67-250	The Information Systems Milieux -Spring	9
67-262	Database Design and Development -Fall	9
67-272	Application Design and Development -Spring	12
67-373	Information Systems Consulting Project -Spring	12
05-391	Designing Human Centered Software	12
or 05-410	User-Centered Research and Evaluation	
or 05-452	Service Design	
17-313	Foundations of Software Engineering	12
95-422	Managing Digital Transformation	9

International Relations & Political Science Concentration

(81 units minimum)

Offered through the Carnegie Mellon Institute for Strategy and Technology (CMIST), the International Relations and Political Science (IRPS) BHA concentration is for students who want to learn how to think systematically and develop foundational knowledge about international and domestic politics. It is an interdisciplinary major that is rooted firmly in political science and draws on strengths and insights from decision science, economics, history, modern languages, and other fields. IRPS students wrestle with a wide range of issues including the future of democracy, the relationship between technology and politics, the drivers of war and peace, domestic politics across countries, and the formulation of effective foreign policies. IRPS graduates embark on a variety of careers in government, law, public policy, intelligence, national defense, consulting, international development, and more.

Core disciplinary courses for the IRPS major establish a strong foundation in the study of political science and enable students to better understand the workings of political institutions, political behavior across countries, the decision-making of political leaders, the making national and international policy, and prevailing challenges to the international system, among other topics.

Core methodology courses train IRPS students in the social science tools and communications skills needed to analyze and write persuasively about international relations and politics. Students pursuing an IRPS major learn to use a wide range of analytic tools including statistics and data science, qualitative analysis, game theory, and behavioral decision-making models as they study politics and strategy. Students also learn how to effectively communicate their analyses to affect public policy.

A rich set of electives allows students to investigate issues in security and technology, grand strategy and national security, cybersecurity and international conflict, military strategy and doctrine, the politics of key regions of the world, international political economy and economic policy, representation and voting rights, climate change and development, repression and human rights, international law and diplomacy, political psychology and public opinion, and social change and revolution.

Recognizing the influence of language and culture on politics, students are required to complete the intermediate (200) level, or its equivalent, in a modern language other than English. Advanced-level study is strongly encouraged.

Prerequisite

84-110	The Economics of Politics, Policy, and Technology	9
or 73-102	Principles of Microeconomics	
or 73-103	Principles of Macroeconomics	

Core Courses (6 courses, 54 units)

84-104	Decision Processes in American Political Institutions	9
84-226	International Relations	9
84-250	Writing for Political Science and Policy	9
84-266	Research Design for Political Science	9
84-275	Comparative Politics	9
36-202	Methods for Statistics & Data Science	9

Language Requirement

BHA IRPS students are required to complete the intermediate II level or the equivalent in a modern language other than English. The language requirement may be satisfied by the BHA General Education Languages, Cultures, and Applied Linguistics requirement if the 200-level is reached. Advanced level study is strongly encouraged.

Electives (3 courses, 27 units minimum)

International Relations and Political Science BHA students must take 27 units (three courses) from the elective lists below. Two courses (18 units) must be taken from the Carnegie Mellon Institute for Strategy and Technology (CMIST) and have an 84-number.

CMIST Electives		
84-120	Introduction to US Constitutional Law	9
84-200	Security War Game Simulation	6
84-252	Briefing in the Policy World	6
84-274	An Introduction to Technology and War	9
84-280	Popcorn and Politics: American Foreign Policy at the Movies	10
84-303	International Human Rights	6
84-304	In the News: Analysis of Current US National Security Priorities	6
84-306	Latin American Politics	9
84-309	American Political Divides and Great Debates	9
84-312	Terrorism in Sub-Saharan Africa	6
84-317	Defense PPBE in the Age of Emerging Technologies	6
84-318	Politics of Developing Nations	9
84-319	Civil-Military Relations	9
84-322	Nonviolent Conflict and Revolution	9
84-323	War and Peace in the Contemporary Middle East	9
84-324	The Future of Democracy	9
84-325	Contemporary American Foreign Policy	9
84-328	Military Strategy and Doctrine	9
84-329	Asian Strategies	6
84-349	Digital Diplomacy: Cybersecurity Challenges and Global Governance	9
84-350	A Strategist's Introduction to Artificial Intelligence	9
84-351	Bias, Objectivity, and the Media's Role in Politics	6
84-352	Representation and Voting Rights	9
84-354	The American Experiment: Unravelling the US Electoral System	6
84-355	Democracy's Data: Analytics and Insights into American Elections	9
84-362	Diplomacy and Statecraft	9
84-363	Click. Hack. Rule: Understanding the Power & Peril of Cyber Conflict	9
84-365	The Politics of Fake News and Misinformation	9
84-367	The Politics of Antisemitism	9
84-369	Decision Science for International Relations	9
84-370	Nuclear Security & Arms Control	9
84-372	Space and National Security	9
84-373	Emerging Technologies and International Law	9
84-380	US Grand Strategy	9
84-383	Cyber Policy as National Policy	6
84-386	The Privatization of Force	9
84-387	Remote Systems and the Cyber Domain in Conflict	9
84-388	Concepts of War and Cyber War	6
84-389	Terrorism and Insurgency	9
84-390	Social Media, Technology, and Conflict	9
84-393	Legislative Decision Making: US Congress	9
84-402	Judicial Politics and Behavior	9
84-405	The Future of Warfare	9
84-440	Collaborative Research in Political Science	Var.

Additional Electives		
19-452	EPP Projects II	12
70-342	Managing Across Cultures	9
70-365	International Trade and International Law	9
70-430	International Management	9

73-332	Political Economy	9
76-318	Communicating in the Global Marketplace	9
79-203	The Other Europe: The Habsburgs, Communism, & Central/Eastern Europe, 1740-1990	9
79-205	20th Century Europe	9
80-136	Social Structure, Public Policy & Ethics	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-229	The Origins of the Palestinian-Israeli Conflict, 1880-1948	9
79-230	The Arab-Israeli Conflict and Peace Process Through 1948 to Present	9
79-257	Germany and the Second World War	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-264	Tibet and China: History and Propaganda	9
79-265	Russian History: Game of Thrones	9
79-266	Russian History and Revolutionary Socialism	9
79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-275	Introduction to Global Studies	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-301	History of Surveillance: From the Plantation to Data Capitalism	6
79-302	Killer Robots? The Ethics, Law, and Politics of Drones and A.I. in War	9
79-313	"Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration	6
79-314	How Do We Remember? The Politics and Cultures of Memory	9
79-318	Sustainable Social Change: History and Practice	9
79-320	Women, Politics, and Protest	9
79-343	Education, Democracy, and Civil Rights	9
79-377	Food, Culture, and Power: A History of Eating	9
79-385	Out of Africa: The Making of the African Diaspora	9
80-135	Introduction to Political Philosophy	9
80-136	Social Structure, Public Policy & Ethics	9
80-249	AI, Society, and Humanity	9
80-335	Social and Political Philosophy	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9
82-3xx	or 4xx Advanced Level Modern Language Course	
88-281	Topics in Law: 1st Amendment	9
88-284	Topics of Law: The Bill of Rights	9
88-411	Rise of the Asian Economies	9

Japanese Studies Concentration

(84 units minimum)

A BHA concentration in Japanese Studies promotes not just language proficiency but also an understanding of Japanese culture. Students who arrive at Carnegie Mellon with previous language study and/or who have high Advanced Placement, an International Baccalaureate, a Cambridge GCE Advanced level or internal placement exam scores will be able to begin taking courses in the concentration earlier in their undergraduate program. In all cases, progress in the concentration will be accelerated by study abroad, which is recommended for all students.

Prerequisites

Low-intermediate-level proficiency in Japanese. This is equivalent to the completion of three courses (two at the 100-level and one at the 200-level) or may be demonstrated through CMU internal placement test scores.

Core Courses in Languages, Cultures and Applied Linguistics (LCAL) (1 course, 9 units)

Complete one course.

82-282	Interpreting Global Texts & Cultures	9
82-283	Language Diversity & Cultural Identity	9
82-482	Introduction to Translation	9

Foundational Courses in Japanese Studies (4 courses, 39 units)

82-272	Intermediate Japanese II	12
82-273	Introduction to Japanese Language and Culture	9
82-371	Advanced Japanese I: An Exploration of Critical Global Topics	9
82-372	Advanced Japanese II -Changes in Japan II: Lifestyle/Religion and Gender	9

Japanese Studies Electives (4 courses, 36 units)

In consultation with the concentration advisor, choose three courses taught in Japanese and one course taught in English.

Linguistics Concentration

(81 units minimum)

The BHA concentration in Linguistics combines courses from the departments of English, Languages, Cultures, and Applied Linguistics, Philosophy and Psychology and the Language Technologies Institute. Linguistics is the study of human language, and it encompasses a broad spectrum of research questions, approaches and methodologies. Some linguists are concerned with the cognitive aspects of language learning, production and comprehension; some are concerned with language as a social and cultural phenomenon; others engage in the analysis of linguistic form and meaning, some from a functional and others from a formal perspective. There are also computational approaches to linguistics with both applied and theoretical goals.

Introductory Course (1 course, 9 units)

80-180	Nature of Language: An Introduction to Linguistics	9

Linguistics Core (2 courses, 18 units)

Take one course each in two of the following three areas.

Sounds:

80-282	Phonetics and Phonology I	9

Structure:

80-280	Linguistic Analysis	9
80-285	Natural Language Syntax	9

Meaning:

80-381	Meaning in Language	9
80-383	Language in Use	9

Extended Core (3 courses, 27 units)

Choose three courses from Extended Core or additional courses from the Linguistics Core above.

76-389	Rhetorical Grammar	9
80-283	It Matters How You Say It	9
80-286	Words and Word Formation: Introduction to Morphology	9
80-287	Language Variation and Change	9
80-288	Intonation: The Meaning of Linguistic Tunes	9
80-382	Phonetics and Phonology II	9
80-384	Linguistics of Turkic Languages	9
80-385	Linguistics of Germanic Languages	9
80-388	Linguistic Typology: Diversity and Universals	9
80-488	Acoustics of Human Speech: Theory, Data, and Analysis	9

Elective Courses (3 courses, 27 units)

Take three additional electives. These can be additional courses from the Core or Extended Core courses listed above, the electives list below, or any other course which must be approved by the concentration advisor as a linguistics elective. Listed below are the additional electives taught on a regular basis. Additional appropriate courses are offered irregularly or on a one-off basis. The concentration advisor will provide students with a list of possible electives each semester, and will assist students in selecting electives that are consistent with their goals and interests. A list of these courses must be filed in the BXA office.

Philosophy:

80-484	Language and Thought	9

English:

76-318	Communicating in the Global Marketplace	9
76-325	Intertextuality	9
76-386	Language & Culture	9
76-388	Coding for Humanists	9
76-389	Rhetorical Grammar	9

Languages, Cultures, and Applied Linguistics:

82-239	Crazy Linguistically Rich Asian Languages	9
82-334	Structure of Chinese	9
82-373	Structure of the Japanese Language	9
82-383	Second Language Acquisition: Theories and Research	9
82-387	Introduction to Linguistic Data Analysis Using R	9

Psychology:

85-354	Infant Language Development	9
85-421	Language and Thought	9

Language Technologies Institute:

11-411	Natural Language Processing	12
11-423	ConLanging: Lrng. Ling. & Lang Tech via Constru Artif. Lang.	12
11-492	Speech Technology for Conversational AI	12

Statistics and Data Science:

36-468	Special Topics: Text Analysis	9

Literature & Culture Concentration

(81 units minimum)

The BHA concentration in Literature & Culture teaches students how to read, interpret and write persuasively about novels, poems, plays and other imaginative works across a variety of genres and media forms. Along with teaching students the analytical skills and methodological tools to interpret these works, this major teaches the importance of understanding imaginative works within their cultural and historical contexts. In addition, the concentration is designed to train students in strong professional and academic skills like critical thinking, inductive reasoning and persuasive argumentation that are applicable to other fields of study and a variety of career paths.

Prerequisite Course

Choose one course:

76-260	Introduction to Writing Fiction	9
76-261	Intro to Writing Creative Nonfiction	9
76-265	Introduction to Writing Poetry	9
76-269	Introduction to Screenwriting	9

Required Introductory Courses (2 courses, 18 units)

76-245	Shakespeare: Tragedies & Histories	9
or 76-247	Shakespeare: Comedies and Romances	
76-275	Introduction to Critical Writing	9

200-Level Literature & Culture Course (1 course, 9 units)

Course options include but are not limited to the following:

76-203	Literature & Culture in the 18th Century	9
76-207	Special Topics in Literature & Culture	9
76-210	Banned Books	9
76-217	Literature & Culture of the 20th and 21st Century	9
76-220	Mystery: From Detective Fiction to True Crime	9
76-221	Books You Should Have Read By Now	9
76-230	Literature & Culture in the 19th Century	9
76-233	Literature and Culture in the Renaissance	9
76-241	Introduction to Gender Studies	9
76-244	Immigrant Fictions	9
76-245	Shakespeare: Tragedies & Histories (if not taken as Required Introductory Course)	9
76-247	Shakespeare: Comedies and Romances (if not taken as Required Introductory Course)	9

300-Level Course (1 course, 9 units)

Course options include but are not limited to the following:

76-310	Advanced Studies in Film and Media	9
76-314	Data Stories	9
76-316	Topics in Literature: Watching HBO's The Watchmen	9
76-317	Contemporary American Fiction	9
76-326	Contemporary Global Literature	9
76-329	Performing Race in Early Modernity	9
76-337	Intersectional Feminism (if not taken as a Theory Course)	9
76-339	Topics in Film and Media	9
76-341	Race & Gender in the Age of Jane Austen	9
76-342	Love: A Cultural History	9
76-343	Rise of the American Novel	9
76-367	Fact Into Film: Translating History into Cinema	9

400-Level Course (1 course, 9 units)

Course options include but are not limited to the following:

76-407	Topics in Literary & Cultural Studies	9
76-408	Culture and Globalization	9
76-410	The Long Eighteenth Century	9
76-423	Transnational Feminisms	9
76-429	Introduction to Digital Humanities	9
76-437	Global Realisms: (if not taken as a Theory Course)	9
76-439	Seminar in Film and Media Studies	9
76-440	Postcolonial Theory: Diaspora and Transnationalism	9
76-442	Black Lives in Pre-1900 Britain	9
76-446	Revenge Tragedy	9
76-448	Shakespeare on Film	9
76-452	Generations and Culture	9
76-458	Sociology of Literature & Culture	9
76-467	Crime Fiction and Film	9
76-468	Space and Mobilities	9
76-495	Other People's Words: The History, Theory, and Practice of Interviews	9

Theory Course (1 course, 9 units)

Course options include but are not limited to the following:

76-337	Intersectional Feminism (if not taken as a 300-Level Course)	9
76-437	Global Realisms: (if not taken as a 400-Level Course)	9
76-458	Sociology of Literature & Culture (if not taken as a 400-Level Course)	9

Rhetoric Course (1 course, 9 units)

Course options include but are not limited to the following:

76-318	Communicating in the Global Marketplace	9
76-351	Rhetorical Invention	9
76-373	Argument	9
76-384	Race, Nation, and the Enemy	9
76-388	Coding for Humanists	9
76-389	Rhetorical Grammar	9
76-415	Mediated Power and Propaganda	9
76-418	Rhetoric and the Body	9
76-475	Law, Performance, and Identity	9
76-476	Rhetoric of Science	9
76-492	Rhetoric of Public Policy	9
76-496	Research Methods in Rhetoric & Writing Studies (permission required from instructor)	9

English Elective Courses (2 courses, 18 units)

Complete two additional courses from the English Department’s offerings. One course must be at the 300-level, and one must be at the 400-level. Electives may include any courses offered by the English Department from any specialization area, with the exception of creative writing workshops.

Logic & Computation Concentration

(81 units minimum)

Students in the program take a common core of courses in logic, methodology, and computer science, together with an associated seminar in their senior year. The individual focus is achieved by selecting a sequence of four advanced and closely related courses. It is in this area of focus (or specialization) that students write their senior thesis under the supervision of a faculty member.

The resulting education in logic, analytic philosophy, mathematics, statistics and computer science enables students to pursue professional careers or graduate study. The analytic and communication skills developed in the major support a wide range of career choices, including those among the fields of technology, business and law. Fields of graduate study for which students are well prepared include, for example, computer science, cognitive science, philosophy, logic and linguistics.

Prerequisites

80-211	Logic and Mathematical Inquiry (Recommended prior to 21-127)	9
15-112	Fundamentals of Programming and Computer Science	12
21-127	Concepts of Mathematics	12

Logic & Computation Core (5 courses, 51 units)

15-122	Principles of Imperative Computation	12
15-150	Principles of Functional Programming	12
80-150	Nature of Reason	9
80-310	Formal Logic	9
80-311	Undecidability and Incompleteness	9

Logic & Computation Electives (3-4 courses, 30 units minimum)

Bearing in mind prerequisites, Logic & Computation students must complete at least three advanced courses in areas that use logical and computational tools, such as philosophy, computer science, linguistics, mathematical logic, psychology or statistics. The sequence of courses, mostly at the 300-level, must be selected in consultation with the concentration advisor.

Philosophy Concentration

(81 units minimum)

The BHA Concentration in in Philosophy provides students with a broad humanities education and sharpens their analytical skills. We encourage, but do not require, students to choose a thematic concentration through their electives. Sample curricula emphasizing Pre-Law, Metaphysics and Epistemology, Ethics and Social Philosophy, and Philosophy of Mind are suggested below. However, alternative emphases can be proposed and approved by the concentration advisor.

In any of the areas listed, substitutions of courses that cohere with a student's interest may be allowed with approval from the concentration advisor.

Introduction to Philosophy (1 course, 9 units)

80-100	Introduction to Philosophy	9

Area 1: Values and Normative Theory (1 course, 9 units)

80-130	Introduction to Ethics	9
80-234	Race, Gender, and Justice	9
80-135	Introduction to Political Philosophy	9
80-136	Social Structure, Public Policy & Ethics	9
80-244	Environmental Ethics	9
80-245	Medical Ethics	9
80-246	Moral Psychology	9
80-249	AI, Society, and Humanity	9
80-330	Ethical Theory	9
80-335	Social and Political Philosophy	9
80-336	Philosophy of Law	9
80-348	Health, Human Rights, and International Development	9
80-447	Global Justice	9

Area 2: Philosophy of Mind/Language/Metaphysics (1 course, 9 units)

80-180	Nature of Language: An Introduction to Linguistics	9
80-270	Problems of Mind and Body: Meaning and Doing	9
80-271	Mind and Body: The Objective and the Subjective	9
80-276	Philosophy of Religion	9
80-280	Linguistic Analysis	9
80-282	Phonetics and Phonology I	9
80-283	It Matters How You Say It	9
80-285	Natural Language Syntax	9
80-286	Words and Word Formation: Introduction to Morphology	9
80-287	Language Variation and Change	9
80-288	Intonation: The Meaning of Linguistic Tunes	9
80-381	Meaning in Language	9
80-382	Phonetics and Phonology II	9
80-383	Language in Use	9
80-384	Linguistics of Turkic Languages	9
80-385	Linguistics of Germanic Languages	9
80-388	Linguistic Typology: Diversity and Universals	9

Area 3: Logic/Philosophy of Mathematics (1 course, 9 units)

80-210	Logic and Proofs	9
80-211	Logic and Mathematical Inquiry	9
80-212	Arguments and Logical Analysis	9
80-310	Formal Logic	9
80-311	Undecidability and Incompleteness	9
80-312	Mathematical Revolutions	9
80-315	Logics for Knowledge and Belief	9
80-411	Proof Theory	9
80-413	Category Theory	9
80-419	Interactive Theorem Proving	9
80-514	Categorical Logic	9

Area 4: Epistemology/Methodology (1 course, 9 units)

80-150	Nature of Reason	9
80-201	Knowledge and Justified Belief	9
80-208	Critical Thinking	9
80-220	Philosophy of Science	9
80-221	Philosophy of Social Science	9
80-226	The Nature of Scientific Revolutions	9
80-261	Experience, Reason, and Truth	9
80-305	Game Theory	9
80-306	Decision Theory	9
80-324	Philosophy of Economics	9
80-516	Causality and Machine Learning	9
80-521	Seminar on Formal Epistemology: Belief and Evidence	9
80-325	Foundations of Causation and Machine Learning	9

Area 5: History of Philosophy (1 course, 9 units)

80-150	Nature of Reason	9
80-226	The Nature of Scientific Revolutions	9
80-250	Ancient Philosophy	9
80-251	Modern Philosophy	9
80-252	Kant	9
80-253	Continental Philosophy	9
80-254	Analytic Philosophy	9
80-261	Experience, Reason, and Truth	9
80-350	Adam Smith	9
80-551	Seminar on History of Philosophy: Smith and Hume	9

Area 6: Electives (3 courses, 27 units)

Three other philosophy courses, or appropriate courses from other departments, with the permission of the concentration advisor.

Policy & Management **Concentration**

(87 units minimum)

The Policy & Management concentration prepares students for key decision-making and management roles in government, non-profit organizations and business. The concentration emphasizes analytical approaches to decision making, practical management skills and empirical techniques necessary for graduates to excel in the public and private sectors. The multidisciplinary curriculum merges frontier knowledge on the ideals of decision making, policy and data analysis, as well as the realities of individual behavior within various institutional settings that must be confronted if high-quality outcomes are to be attained.

The Policy & Management concentration provides an excellent combination of theoretical and practical skills for students who intend to seek managerial positions. Because of its strong analytic orientation, it is also an excellent concentration for those who intend to go on to professional school programs in law, business or public policy. It is also an appropriate choice for students pursuing graduate degrees in economics, political science or decision science.

Policy Core (2 courses, 18 units)

The Policy Core gives students applied economic training and policy analysis experience. Students will gain an analytical understanding of some of the biggest domestic and global economic policy challenges, and gain an appreciation of the economic analysis of complex decisions, as well as the trade-off between economic and political-based decision making.

73-102	Principles of Microeconomics	9
88-221	Markets, Democracy, and Public Policy	9

Management Core (3 courses, 30 units)

The Management Core focuses on real-world applications of decision making. Students will develop an understanding of effective negotiation strategies and tactics, and identify the barriers and the psychological factors that may prevent decision-makers from reaching wise agreements. The courses provide systematic methods for dealing with the complexities that make decisions difficult, ranging from incorporating issues of risk and uncertainty in decision making to dealing with choices that have mutually conflicting objectives. For example, a business or government agency may need to decide on a policy for mitigating the uncertain impacts of air pollution while simultaneously trying to minimize the costs of such a policy on manufacturing. A firm might want to consider the uncertain reductions in security dangers from alternative policies to protect against terrorism.

88-150	Managing Decisions	9
or 88-255	Strategic Decision Making	
88-223	Decision Analysis	12
88-235	Negotiation: Strategies and Behavioral Insights	9
or 88-234	Negotiation: International Focus	

Empirical Core (3 courses, 27 units)

The Empirical Core focuses on key methods for collecting and analyzing data that are needed to make informed decisions. Students learn to use interviews, surveys, experiments and econometric methods to enhance their ability to test existing, and design new policies. Students will create statistical models to address questions asked in conceptual, computational and data-driven investigations.

36-202	Methods for Statistics & Data Science	9
88-251	Empirical Research Methods	9
88-252	Causal Inference: from Data to Decisions	9
or 88-275	Bubbles: Data Science for Human Minds	

Senior Project (1 course, 12 units)

The required Senior Project course gives students hands-on experience in a policy-related area. Students work in teams to apply the research and analytical methods learned in their other courses to a real-world problem.

88-451/452	Policy Analysis Senior Project	12

Politics & Public Policy **Concentration**

(81 units minimum)

Rooted in the discipline of political science, the concentration in Politics and Public Policy investigates US public policy issues and matters of American politics and law while providing students hands-on and practical learning experiences. Students pursuing the Politics and Public Policy concentration must participate in the Carnegie Mellon University Washington Semester Program (CMU/WSP) (https://www.cmu.edu/ips/washington-dc-semester-program/) for one semester during their undergraduate years.

The CMU/WSP, sponsored by the Carnegie Mellon Institute for Strategy and Technology (CMIST), is a semester-long program in which students live, intern, and take CMU classes in Washington, DC. Undergraduates from any course of study at the university may participate in the program. Students earn 48 units for the Carnegie Mellon University Washington Semester Program, interning about twenty-four hours per week in any sector or field of interest within Washington, DC, while taking classes on American politics, public policy, and law taught by Carnegie Mellon faculty.

From embassies to nongovernmental organizations, think tanks to advocacy organizations, government agencies to congressional offices, and consulting firms to media outlets, Washington, DC, is the center of US political, international, and public policy activities. Students in the program come into direct contact with policymakers, Congressmen, think tank leaders, and business leaders, and through hands-on experience learn about the most pressing policy issues of the day.

Through this experiential learning program, CMU/WSP participants develop professional and networking skills, explore how coursework connects to the real world, learn to give and receive constructive feedback in the workplace and classroom, and intentionally reflect on their learning and growth. Every CMU/WSP student is paired with a Washington, DC- based alumni mentor to share career advice and tips about life in DC. CMIST also sponsors events and policy-oriented opportunities in Washington for students participating in the program to further enrich their experience and enhance their understanding of how Washington functions as a hub of international and domestic policy decision making.

Foundational Course (1 course, 9 units)

Students must complete the following course:

84-104	Decision Processes in American Political Institutions	9

Economics or Data Science Course (1 course, 9 units)

Students must complete one of the following courses:

84-110	The Economics of Politics, Policy, and Technology	9
or 73-102	Principles of Microeconomics	
or 73-103	Principles of Macroeconomics	
or 36-202	Methods for Statistics & Data Science	

CMU/WSP Seminars in Washington, DC (4 courses, 48 units)

Students must take the following courses while participating in the CMU/WSP:

84-360	CMU/WSP: Internship Seminar	24
84-336	Implementing Public Policy: From Good Idea To Reality	12
or 84-339	Seminar in Public Policy Research	
84-332	Contemporary US Constitutional Law Issues	6
84-338	Analysis of US Presidential Powers	6

American Politics Courses in Pittsburgh (2 courses, 15 units minimum)

Students must take two courses (15 units minimum) from the below list of electives taught in Pittsburgh.

84-120	Introduction to US Constitutional Law	9
84-252	Briefing in the Policy World	6
84-280	Popcorn and Politics: American Foreign Policy at the Movies	10
84-304	In the News: Analysis of Current US National Security Priorities	6
84-309	American Political Divides and Great Debates	9
84-319	Civil-Military Relations	9
84-325	Contemporary American Foreign Policy	9
84-351	Bias, Objectivity, and the Media's Role in Politics	6
84-352	Representation and Voting Rights	9
84-354	The American Experiment: Unravelling the US Electoral System	6
84-355	Democracy's Data: Analytics and Insights into American Elections	9
84-362	Diplomacy and Statecraft	9
84-365	The Politics of Fake News and Misinformation	9
84-367	The Politics of Antisemitism	9
84-380	US Grand Strategy	9

84-393	Legislative Decision Making: US Congress	9
84-402	Judicial Politics and Behavior	9

Professional Writing Concentration

(84 units minimum)

Professional Writing combines liberal and professional education with a strong foundation in rhetorical studies. The concentration in Professional Writing has a strong career orientation and is specifically designed to prepare students for successful careers as writers and communications specialists in a range of fields: publishing, government, journalism, the non-profit sector, education, public and media relations, corporate communications, advocacy writing and the arts. The concentration is designed to develop articulate and reflective communications professionals with both the skills needed to enter and negotiate current work contexts (including writing for the web and other digital media) and the analytic and problem-solving skills needed to understand and keep pace with cultural and technological change.

Prerequisite English Elective

Students with a concentration in Professional Writing must complete one perquisite course from the English Department's offerings, which focuses on the relationships between texts and their cultural and historical contexts. The course must be at or above the 200 level. 76-270 Writing for the Professions, and 76-271 Introduction to Professional and Technical Writing may not count as English electives. Appropriate courses are advertised every semester in the English department's "What Counts for What" list.

Foundation Courses (5 courses, 39 units)

76-26x	Introductory Genre Writing Course (Nonfiction, Fiction, Poetry or Screenwriting)	9
76-271	Introduction to Professional and Technical Writing	9
76-300	Professional Seminar	3
76-373	Argument	9
76-390	Style	9

Rhetoric/Language Studies Course (1 course, 9 units)

Students with a concentration in Professional Writing complete one course from designated Rhetoric courses offered and advertised each semester by the English Department. Rhetoric courses focus on understanding the role of language and language practices in both personal and professional contexts. Courses emphasize the relationships between texts and their contexts and pay particular attention to textual features, meaning, processes of reading and writing, and the ways in which language practices vary over time and across situations and cultures. The courses also equip students with explicit techniques for analyzing, understanding and exploring language practices. The Rhetoric/Language Studies courses may also be taken as part of the concentration requirements for three additional, Advanced Writing/Rhetoric courses and include but are not limited to the following list.

76-325	Intertextuality	9
76-351	Rhetorical Invention	9
76-360	Literary Journalism Workshop	9
76-384	Race, Nation, and the Enemy	9
76-388	Coding for Humanists	9
76-389	Rhetorical Grammar	9
76-395	Science Writing	9
76-415	Mediated Power and Propaganda	9
76-473	Rhetoric & the Construction of Race	9
76-474	Software Documentation	9
76-476	Rhetoric of Science	9
76-494	Healthcare Communications	9

Advanced Writing/Rhetoric Courses (3 courses, 27 units minimum)

Students with a concentration in Professional Writing complete three Advanced Writing/Rhetoric courses at the 300- or 400-level at a minimum of 27 units, as some courses are only six units, while others are variable units. Options for these courses include all of the Rhetoric/Language Studies courses listed above plus the writing-focused courses listed below. Additional courses that fulfill these requirements are advertised on a semester-by-semester basis. For help in choosing which of the possible options are most appropriate for various professional goals – journalism, writing for new media, editing and publishing, public relations/corporate communications, or science and technical writing – consult your English Department advisor. All students with a concentration in PW, regardless of their career focus, are encouraged to take 76-391 Document & Information Design and 76-487 Information Architecture & Content Strategy (formerly titled Web Design) to extend their skills in writing for print to include information design for digital media. Both courses focus on the role of the writer in these specializations and provide lab instruction in the relevant software and related computer skills.

Courses include but are not limited to:

76-301	Internship	Var.
76-302	Communication Support Tutoring Practicum	6
76-314	Data Stories	9
76-351	Rhetorical Invention	9
76-354	Watchdog Journalism	9
76-360	Literary Journalism Workshop	9
76-372	News Writing	9
76-380	Methods in Humanities Analytics	9
76-388	Coding for Humanists	9
76-389	Rhetorical Grammar	9
76-391	Document & Information Design	9
76-395	Science Writing	9
76-415	Mediated Power and Propaganda	9
76-418	Rhetoric and the Body	9
76-425	Rhetoric, Science, and the Public Sphere	9
76-464	Creative Nonfiction Workshop	9
76-474	Software Documentation	9
76-475	Law, Performance, and Identity	9
76-476	Rhetoric of Science	9
76-481	Introduction to Multimedia Design	12
76-483	Research Methods in Technical & Professional Communication	9
76-487	Information Architecture & Content Strategy (co-requisite with 76-488)	9
76-488	Information Architecture & Content Strategy Lab (co-requisite with 76-487)	3
76-492	Rhetoric of Public Policy	9
76-494	Healthcare Communications	9
76-496	Research Methods in Rhetoric & Writing Studies (instructor permission required)	9

English Elective (1 course, 9 units minimum)

Students with a concentration in Professional Writing complete one additional course from the English Department's offerings. This course should be one that focuses on the relationships between texts and their cultural and historical contexts. Courses in literature, cultural studies, rhetoric and media studies that meet this requirement are advertised on a semester-by-semester basis. The English Elective may be any course offered by the Department with the exception of 76-270 Writing for the Professions, which is designed for non-majors and overlaps with 76-271 Introduction to Professional and Technical Writing.

Psychology Concentration

(81 units minimum)

Psychology is a science that embraces both biological and social sciences. It is a science concerned with establishing principles and laws regarding the ways in which people think, feel, and behave through the scientific study of human behavior. Students with a concentration in Psychology are expected not only to learn about findings already established by psychologists, but also to become proficient in the investigation and analysis of behavior. This includes observing behavior, formulating hypotheses, designing experiments to test these hypotheses, running experiments, performing statistical analyses and writing reports.

Breadth Courses (4 courses, 36 units)

To gain familiarity with the breadth of the field of Psychology, students take 85-102 Introduction to Psychology and three survey courses.

Required Intro Course:

85-102	Introduction to Psychology	9

Survey Courses:

85-104	Psychopathology	9
85-211	Cognitive Psychology	9
or 85-213	Human Information Processing and Artificial Intelligence	
85-219	Foundations of Brain and Behavior	9
85-221	Principles of Child Development	9

85-241	Social Psychology	9
85-251	Personality	9

Research Methods and Statistics (3 courses, 27 units)

Students complete two courses in Research Methods (18 units). The corresponding survey course is a prerequisite.

85-300	Introduction to Research Methods	9
85-310	Research Methods in Cognitive Psychology	9
85-314	Cognitive Neuroscience Research Methods	9
85-320	Research Methods in Developmental Psychology	9
85-330	Analytic Research Methods	9
85-340	Research Methods in Social Psychology	9

The following Statistics course is a prerequisite for all the Research Methods courses. This Statistics course counts toward the Psychology concentration.

36-309	Experimental Design for Behavioral & Social Sciences -Fall	9
or 85-309	Statistical Concepts and Methods for Behavioral and Social Science	

Advanced Courses (2 courses, 18 units)

Complete any two advanced courses or seminars in Psychology numbered higher than 85-349. (excepting 85-480, 85-482, 85-484, 85-506, 85-507, 85-508).

Russian Studies Concentration

(84 units minimum)

A BHA concentration in Russian Studies promotes not just language proficiency but also an understanding of Russian culture. Students who arrive at Carnegie Mellon with previous language study and/or who have high Advanced Placement, an International Baccalaureate, a Cambridge GCE Advanced level or internal placement exam scores will be able to begin taking courses in the concentration earlier in their undergraduate program. In all cases, progress in the concentration will be accelerated by study abroad, which is recommended for all students.

Prerequisites

There are no language prerequisites for the Russian major. Students with native or near-native proficiency in Russian or with prior study at the elementary or intermediate level may begin language study at a higher level, based on consultation with the concentration advisor and placement through CMU placement tests.

Core Courses in Russian Language (4 courses, 39 units minimum)

Complete at least four semesters of Russian language study. Students who take Intensive Elementary Russian and those who place into higher level courses will still need to complete four semesters of language study.

82-191	Elementary Russian I	12
82-292	Intermediate Russian II	12
82-291	Intermediate Russian I	12
82-292	Intermediate Russian II	12
82-194	Intensive Russian (I & II)	15

Core Courses in Languages, Cultures and Applied Linguistics (LCAL) (1 course, 9 units)

82-282	Interpreting Global Texts & Cultures	9

Foundational Courses in Russian Studies (2 course, 18 units)

82-294	19th Century Russian Masterpieces	Var.
or 82-295	20th Century Russian Masterpieces	
79-269	Russian History: From Socialism to Capitalism *	9

* *Other courses with a historical focus are available in the Department of History or LCAL. Please consult the concentration advisor for more options.*

Russian Studies Electives (2 courses, 18 units)

In consultation with the concentration advisor, choose two additional courses focusing on Russia, Eastern Europe, or Eurasia. Students may substitute one relevant and related course from outside the program (i.e., another LCAL course) or from another department (e.g., History, CMIST, Philosophy, English).

Social & Political History Concentration

(84 units minimum)

The BHA concentration in Social & Political History focuses on new ways to understand the past and new ways to use what we know, as well as on connections between past and present and on how historical knowledge facilitates understanding of social, cultural and policy change. The History concentration emphasizes empirical methods and conceptual analysis, as well as specific research skills relevant to many types of jobs and further professional training. The History concentration combines a structured sequence of courses, training in research methods, theoretical concepts, and analytical writing skills, plus a considerable array of electives.

The BHA concentration in Social & Political History emphasizes broad-based, cumulative knowledge and interpretive skills in the study of the past. Offerings at the 200- and 300-level are designed to allow maximum flexibility in meeting requirements and maximum choice in focusing on particular themes, places, or eras. Upper-level courses aim to give students majoring in History more time together in smaller classes and more experience working with primary and secondary sources. The senior capstone seminar, Historical Research Seminar, provides training and experience in conducting original research and in interpretive, analytical writing—skills that prepare graduates for professional careers as well as for graduate or law school.

Required History Courses (2 courses, 21 units)

Students must earn a final grade of “C” or better for these courses to count toward the concentration.

79-200	Introduction to Historical Research & Writing - Sophomore or Junior year	9
79-420	Historical Research Seminar -Fall, Senior year	12

Required Survey Courses (2 courses, 18 units)

79-120	Introduction to African American History: Black Americans and the World	9
79-160	Introduction to the History of Science	9
79-170	Introduction to Science, Technology, and Society	9
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-203	The Other Europe: The Habsburgs, Communism, & Central/Eastern Europe, 1740-1990	9
79-204	American Environmental History	9
79-205	20th Century Europe	9
79-206	Crime and Punishment in Early Modern Europe	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-212	Jim Crow America	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-225	West African History in Film	9
79-226	African History: Earliest Times to 1780	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-229	The Origins of the Palestinian-Israeli Conflict, 1880-1948	9
79-230	The Arab-Israeli Conflict and Peace Process Through 1948 to Present	9
79-240	Development of American Culture	9
79-242	African American History: Reconstruction to the Present	9
79-244	Women in American History	9
79-245	Capitalism and Individualism in American Culture	9
79-248	U.S. Constitution & the Presidency	9
79-249	20th Century U.S. History	9
79-250	Voting Rights: An Introduction	9
79-260	Nazi Germany	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-265	Russian History: Game of Thrones	9
79-266	Russian History and Revolutionary Socialism	9
79-269	Russian History: From Socialism to Capitalism	9
79-272	Coexistence and Conflict: Muslims, Christians and Jews in Spain and Portugal	9
79-282	Europe and the World Since 1800	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-320	Women, Politics, and Protest	9

Social & Political History Elective Courses (5 courses, 45 units minimum)

A minimum of 45 additional History units must be approved with the History advisor. Any History courses not fulfilling another major requirement may be chosen as an elective. Any History (79-xxx) class can count as an SPH elective except for 79-198, 79-200, 79-400, 79-420, 79-449, 79-491). See the History Department website (www.cmu.edu/dietrich/history (https://www.cmu.edu/dietrich/history/)) or contact the History advisor for the most current elective offerings.

Students may satisfy the elective requirements in SPH with up to 27 units of the following courses offered by other departments in Dietrich College:

73-476	American Economic History	9
76-230	Literature & Culture in the 19th Century	9
76-239	Introduction to Film Studies	9
76-295	Russian Cinema: From the Bolshevik Revolution to Putin's Russia	9
80-135	Introduction to Political Philosophy	9
80-226	The Nature of Scientific Revolutions	9
80-335	Social and Political Philosophy	9
82-245	New Directions in Hispanic Studies	9
82-247	US Latinos Literature	9
82-293	Russian Cinema: From the Bolshevik Revolution to Putin's Russia	9
82-327	The Emergence of the German Speaking World	9
82-420	The Crucible of Modernity:Vienna 1900	9
82-427	Nazi and Resistance Culture	9
84-275	Comparative Politics	9
84-322	Nonviolent Conflict and Revolution	9
84-324	The Future of Democracy	9
84-325	Contemporary American Foreign Policy	9
84-362	Diplomacy and Statecraft	9
84-380	US Grand Strategy	9
84-386	The Privatization of Force	9
84-389	Terrorism and Insurgency	9
85-380	In Search of Mind: The History of Psychology	9
88-281	Topics in Law: 1st Amendment	9
88-284	Topics of Law: The Bill of Rights	9

Statistics Concentration

(81 units minimum)

In the BHA concentration in Statistics, students develop and master a wide array of skills in computing, mathematics, statistical theory, and the interpretation and display of complex data. In addition, students with a BHA concentration in Statistics gain experience in applying statistical tools to real problems in other fields and learn the nuances of interdisciplinary collaboration.

Prerequisites

These courses are not counted as part of your DC Concentration. They may be used to satisfy general education or free elective requirements.

21-120	Differential and Integral Calculus	10
21-256	Multivariate Analysis	9
or 21-259	Calculus in Three Dimensions	
21-240	Matrix Algebra with Applications	10
or 21-241	Matrices and Linear Transformations	
or 21-242	Matrix Theory	
15-110	Principles of Computing	10
or 15-112	Fundamentals of Programming and Computer Science	

Note: 21-240, 21-241, 21-242 must be completed before taking 36-401 Modern Regression. 21-241 and 21-242 are intended only for students with a very strong mathematical background.

Statistics Core (6 courses, 54 units)

36-202	Methods for Statistics & Data Science	9
or 36-290	Introduction to Statistical Research Methodology	
36-235	Probability and Statistical Inference I - (recommended)	9
or 36-225	Introduction to Probability Theory	
36-236	Probability and Statistical Inference II - (recommended)	9
or 36-226	Introduction to Statistical Inference	
36-350	Statistical Computing	9
36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9

Special Topics and Electives (3 courses, 27 units)

Students must take a total of three courses from Special Topics (numbered 36-46x) and Statistics Electives listed below. Students will consult with the concentration advisor to select the Special Topics and Electives courses that best fit for their areas of interest.

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-313	Statistics of Inequality and Discrimination	9
36-315	Statistical Graphics and Visualization	9
36-318	Introduction to Causal Inference	9
36-46x–47x	Special Topics (topics and offerings vary)	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

Statistics & Machine Learning Concentration

(87 units minimum)

In the BHA concentration in Statistics & Machine Learning, develop and master a wide array of skills in computing, mathematics, statistical theory, and the interpretation and display of complex data. In addition, students with a BHA concentration in Statistics & Machine Learning gain experience in applying statistical tools to real problems in other fields and learn the nuances of interdisciplinary collaboration. This program is geared towards students interested in statistical computation, data science or “Big Data” problems.

Prerequisites

These five courses are not counted as part of your DC Concentration. They may be used to satisfy general education or free elective requirements.

21-120	Differential and Integral Calculus	10
21-127	Concepts of Mathematics	12
21-256	Multivariate Analysis	9
or 21-259	Calculus in Three Dimensions	
21-240	Matrix Algebra with Applications	10
or 21-241	Matrices and Linear Transformations	
or 21-242	Matrix Theory	
15-112	Fundamentals of Programming and Computer Science	12

Note: 21-240, 21-241, 21-242 must be completed before taking 36-401 Modern Regression. 21-241 and 21-242 are intended only for students with a very strong mathematical background.

Statistics Core (5 courses, 45 units)

36-235	Probability and Statistical Inference I - (recommended)	9
or 36-225	Introduction to Probability Theory	
36-236	Probability and Statistical Inference II - (recommended)	9
or 36-226	Introduction to Statistical Inference	
36-350	Statistical Computing	9
36-401	Modern Regression	9
36-402	Advanced Methods for Data Analysis	9

Data Analysis Electives (1 course, 9 units)

Students must take one course from the Special Topics (numbered 36-46x–47x) and Statistics Electives listed below. Students will consult with the concentration advisor to select the Special Topics and Electives courses that best fit for their areas of interest.

36-303	Sampling, Survey and Society	9
36-311	Statistical Analysis of Networks	9
36-313	Statistics of Inequality and Discrimination	9
36-315	Statistical Graphics and Visualization	9
36-318	Introduction to Causal Inference	9
36-46x–47x	Special Topics (topics and offerings vary)	9
36-490	Undergraduate Research	9
36-497	Corporate Capstone Project	9

Machine Learning Core (2 courses, 24 units)

15-122	Principles of Imperative Computation -(C or higher)	12
10-301	Introduction to Machine Learning	12

Machine Learning Elective (1 course, 9 units minimum)

Students must take one course from the ML Electives listed below. Students will consult with the Statistics & Machine Learning advisor to choose an elective that best fits their area of interest. This course may have additional pre-requisites. Keep in mind this is not an exhaustive list and other applicable courses can be reviewed to be approved as an ML elective – please speak with the concentration advisor about this.

02-510/710	Computational Genomics	12
05-317	Design of Artificial Intelligence Products	12
05-434/11-344	Machine Learning in Practice	12
10-403/703	Deep Reinforcement Learning & Control	12
10-405/605	Machine Learning with Large Datasets (Undergraduate)	12
10-414	Deep Learning Systems: Algorithms and Implementation	12
10-417	Intermediate Deep Learning	12
10-418/618	Machine Learning for Structured Data	12
10-613	Machine Learning Ethics and Society	12
10-707	Advanced Deep Learning	12
10-708	Probabilistic Graphical Models	12
11-324/624	Human Language for Artificial Intelligence	12
11-411	Natural Language Processing	12
11-441	Machine Learning with Graphs	9
11-485	Introduction to Deep Learning	9
11-661/761	Language and Statistics	12
15-281	Artificial Intelligence: Representation and Problem Solving	12
15-386	Neural Computation	9
15-387	Computational Perception	9
15-482	Autonomous Agents	12
16-311	Introduction to Robotics	12
16-385/720	Computer Vision	12
17-445	Machine Learning in Production	12
85-419	Introduction to Parallel Distributed Processing	9

Technical Writing Concentration

(87 units minimum)

The concentration in Technical Writing is specifically designed to prepare students for successful careers involving scientific, technical, and computer-related communication, including writing and designing for digital media. Technical communicators develop and design web sites, explain science and technology to the public, develop print and multimedia materials, develop information management systems, design and deliver corporate training, and develop support systems for consumer products ranging from software for word processing or personal finances to complex data management systems. The Technical Writing concentration includes with a common core of foundation courses in print and on-line communication as well as a set of prerequisites in math, statistics and computer programming.

Students with a Technical Writing concentration take two Theory/Specialization courses specific to either the Technical Communication (TC) or the Scientific and Medical Communication (SMC) track. In addition, students in the SMC track take two courses in the natural sciences or engineering relevant to their areas of interest, while TC students take two electives in management, technology and social issues.

Prerequisite Courses

21-111	Calculus I	10
or 21-112	Calculus II	
or 21-120	Differential and Integral Calculus	
or 21-127	Concepts of Mathematics	
15-110	Principles of Computing (required for SMC-track students)	10
or 15-112	Fundamentals of Programming and Computer Science	
(required for TC-track students)		

Technical Writing Core Courses (7 courses, 51 units)

76-26x	Introductory Genre Writing Course (Nonfiction, Fiction, Poetry or Screenwriting)	9
76-271	Introduction to Professional and Technical Writing	9
76-300	Professional Seminar	3
76-390	Style	9
76-391	Document & Information Design	9
76-487	Information Architecture & Content Strategy (co-requisite with 76-488)	9
76-488	Information Architecture & Content Strategy Lab (co-requisite with 76-487)	3

Theory/Specialization Courses (3 courses, 27 units minimum)

Complete three courses to deepen your area of specialty in Technical Communication or Scientific and Medical Communication. One course must be chosen from among courses designated as Recommended Options. Check with the English department each semester for additional options.

Recommended Options:

76-314	Data Stories	9
76-327	Equity & Communication: Strategies for Institutional Change	9
76-380	Methods in Humanities Analytics	9
76-395	Science Writing	9
76-425	Rhetoric, Science, and the Public Sphere	9
76-474	Software Documentation	9
76-476	Rhetoric of Science	9
76-481	Introduction to Multimedia Design	12
76-494	Healthcare Communications	9

Additional Options i nclude but are not limited to the following:

76-301	Internship	Var.
76-302	Communication Support Tutoring Practicum	6
76-318	Communicating in the Global Marketplace	9
76-325	Intertextuality	9
76-327	Equity & Communication: Strategies for Institutional Change	9
76-351	Rhetorical Invention	9
76-354	Watchdog Journalism	9
76-360	Literary Journalism Workshop	9
76-372	News Writing	9
76-384	Race, Nation, and the Enemy	9
76-389	Rhetorical Grammar	9
76-391	Document & Information Design	9
76-395	Science Writing	9
76-425	Rhetoric, Science, and the Public Sphere	9
76-474	Software Documentation	9
76-475	Law, Performance, and Identity	9
76-476	Rhetoric of Science	9
76-481	Introduction to Multimedia Design	12
76-484	Discourse Analysis	9
76-487	Information Architecture & Content Strategy (co-requisite with 76-488)	9
76-488	Information Architecture & Content Strategy Lab (co-requisite with 76-487)	3
39-605	Engineering Design Projects	12

Electives (1 course, 9 units)

Students with a Technical Writing concentration take one course outside of English to deepen their area of specialty in their track. Students in the TC track typically select courses from business, design, psychology, and social and decision sciences, or HCI. Students in the SMC track select courses from the natural sciences, computer science, math or statistics, or (for example) healthcare-related courses in the Heinz School. Students should work with the concentration advisor to select courses that are meaningful for their track.

COLLEGE OF FINE ARTS CONCENTRATION

(number of courses vary, 108-130 units minimum)

BHA students choose one of the following concentrations:

- Architecture (108 units)
- Art (114 units)

- Design (108 units)
- Drama (130 units)
- Music (108 units)

Architecture Concentration

(108 units minimum)

Architecture Required Courses (9 courses, 57 units minimum)

48-100	Architecture Design Studio: POIESIS STUDIO 1 -Fall, Freshman or Sophomore year	10-15
or 48-095	Spatial Concepts for Non-Architecture Majors	
48-104	Shop Skills -Fall, Freshman year	2
62-104	Design Ethics & Social Justice in Architecture -Fall, Freshman or Sophomore year	3
62-122	Digital Media I -Fall, Freshman year	6
62-125	Drawing I -Fall, Freshman year	6
62-123	Digital Media II -Spring, Freshman year	6
62-126	Drawing II -Spring, Freshman year	6
48-240	History of World Architecture, I -Spring, Freshman year	9
48-241	History of Modern Architecture -Fall, Sophomore year	9

Architecture Electives (51 units minimum)

A minimum of **51** additional Architecture units must be approved by the Architecture advisor. A list of these selected courses must be filed in the BXA office. 48-025 First Year Seminar: Architecture Edition I (3 units) is recommended in fall of the first year.

Art Concentration

(114 units minimum)

First-Year Seminar (1 course, 6 units)

60-104	Foundations: Art First-Year Seminar	6

Foundation Studios (3 courses, 30 units)

Complete three courses:

60-110	Foundations: Time-Based Media	10
60-120	Foundations: Digital Media	10
60-131	Foundations: Sculpture	10
60-135	Foundations: Sculpture II	10
60-150	Foundations: Drawing	10
60-170	Foundations: Paint/Print	10

Intermediate Studios (3 courses, 30 units)

Complete three courses:

60-2xx	Intermediate Studio Elective	10
60-2xx	Intermediate Studio Elective	10
60-2xx	Intermediate Studio Elective	10

Advanced Studios (3 courses, 30 units)

Students may take courses in any media area (ETB, SIS, CP or DP3). They may take all courses in one media area if a focus is desired. With approval from the Art advisor, BXA students can take an additional intermediate studio in lieu of an advanced studio to increase breadth.

Complete three courses:

60-401/402	Senior Studio	10
60-403	Senior Critique Seminar	10
Advanced Electronic and Time-Based Work (ETB) (course numbers 60-410 through 60-429) *		10
Advanced Sculpture, Installation and Site-Work (SIS) (course numbers 60-430 through 60-447) *		10
Advanced Contextual Practice (CP) (course numbers 60-448 through 60-449) *		10
Advanced Drawing, Painting, Print Media and Photography (DP3) (course numbers 60-450 through 60-498) *		10
60-499	Studio Independent Study (one only)	10

* *Courses offered intermittently; speak with a BXA advisor to determine course availability.*

Critical Studies (2 courses, 18 units)

60-107	Foundations: Critical Studies -Spring	9
60-3xx	Critical Studies Elective	9

Review Requirement (1 required review, 0 units)

Complete required review:

60-200	Sophomore Review -Spring (pass/no pass)	0

Design Concentration

(108 units minimum)

Note: BXA design only considers internal transfer applicants currently enrolled in Design.

Design Required Courses (16 courses, 98 units)

51-101	Studio: Survey of Design -Fall, First-year	10
51-121	Visualizing -Fall, First-year	10
51-175	Design Studies: Place -Fall, First-year (mini-1)	5
51-177	Design Studies: Histories -Fall, First-year (mini-2)	5
51-102	Design Lab -Spring, First-year	10
51-122	Collaborative Visualizing -Spring, First-year	10
51-176	Design Studies: Futures -Spring, First-year (mini-3)	5
51-178	Design Studies: Experience -Spring, First-year (mini-4)	5
51-277	Design Studies: Systems -Fall, Sophomore year (mini-1)	5
51-279	Design Studies: Cultures -Fall, Sophomore year (mini-2)	5
51-282	Design Studies: Persuasion -Spring, Sophomore year (mini-3)	5
51-284	Design Studies: Power -Spring, Sophomore year (mini-4)	5
Choose Two Studios -Fall, Sophomore year:		4.5+4.5
51-225	Communications Studio I: Understanding Form & Context	4.5
or 51-245	Products Studio I: Understanding Form & Context	
or 51-265	Environments Studio I: Understanding Form & Context	
Choose Two Corresponding Labs -Fall, Sophomore year:		4.5+4.5
51-227	Prototyping Lab I: Communications	4.5
or 51-247	Prototyping Lab I: Products	
or 51-267	Prototyping Lab I: Environments	

Design Electives (10 units)

A minimum of **10** additional Design units must be approved by the Design advisor. A list of these selected courses must be filed in the BXA office.

Drama Concentration

(130 units minimum)

Options available in the following areas: 1) Design, 2) Dramaturgy, 3) Production Technology and Management

Note: BXA design only considers internal transfer applicants currently enrolled in Drama design. BXA dramaturgy only considers internal transfer applicants in the fall semester for spring enrollment, unless currently enrolled in Drama dramaturgy. BXA PTM only considers internal transfer applicants currently enrolled in Drama PTM.

Design/PTM Required Courses (10 courses, 75 units)

54-169	Studiocraft 1 -Fall, First-year	13
54-151	Stagecraft -Fall, First-year	6
54-159	Production Practicum -Fall, First-year	6
54-171	Basic Design 1 -Fall, First-year	6
54-170	Studiocraft 2 -Spring, First-year	8
54-152	Stagecraft -Spring, First-year	12
54-158	Production Planning -Spring, First-year	6
54-177	Foundations of Drama I -Spring, First-year or later if needed	6
54-281	Foundations of Drama II	6
54-381	Special Topics: Feminist Theatre	6

Design/PTM Required Courses (55 units minimum)

A minimum of **55** additional Design/PTM units taken in the sophomore year or later must be approved by the Design/PTM faculty area chair. A list of these selected courses must be filed in the BXA office.

Dramaturgy Required Courses (13 courses, 80 units)

54-177	Foundations of Drama I -Fall, First-year	6
54-109	Dramaturgy 1: Approaches to Text -Fall, First-year	9
54-284	Fundamentals of Directing -Fall, First-year	6
54-200	Dramaturgy Forum -Fall, First-year	1
54-159	Production Practicum -Fall or Spring, First-year	6
54-281	Foundations of Drama II -Spring, First-year	6
54-184	Dramaturgy 2: Introduction to Production Dramaturgy -Spring, First-year	9
54-200	Dramaturgy Forum -Spring, First-year	1
54-117	Design Collaboration Project -Spring, First-year	3
54-241	Dramaturgy 3: Dramaturgy in Translation -Fall, Sophomore year	9
54-256	Dramaturgy 4: New Play Dramaturgy -Spring, Sophomore year	9
54-363	Dramaturgy 5 -Fall, Junior year	9
54-381	Special Topics: Feminist Theatre	6

Dramaturgy Electives (50 units minimum)

A minimum of **50** additional Dramaturgy units taken in the sophomore year or later must be approved by the Dramaturgy faculty area chair. A list of these selected courses must be filed in the BXA office.

Music Concentration

(108 units minimum)

Options available in the following areas: 1) Audio Recording & Production, 2) Composition, 2) Music Performance (instrumental, organ, piano, voice), 4) Sound Theory & Practice

Note: BXA music performance only considers internal transfer applicants in the spring semester for fall enrollment, unless currently enrolled in Music performance.

Audio Recording & Production Required Courses (8 courses, 49 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-101	Introduction to Music Technology	6
or 57-171	Introduction to Music Technology (self-paced)	
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-438	Multitrack Recording	9

Audio Recording & Production Electives (59 units minimum)

Choose **59** units from:

57-153	Harmony II	9
or 57-150	Basic Harmony II	
57-182	Solfege II	3
or 57-186	Advanced Solfege II	
10-301	Introduction to Machine Learning	12
15-104	Introduction to Computing for Creative Practice	10
15-213	Introduction to Computer Systems	12
15-322	Introduction to Computer Music	9
18-090	Twisted Signals: Multimedia Processing for the Arts	10
33-114	Physics of Musical Sound	9
54-166	Introduction to Sound Design for Theatre	6
54-666	Production Audio (section B)	4
57-161	Eurhythmics I	3
57-162	Eurhythmics II	3
57-344	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music	6
57-358	Introduction to Electronic Music (with instructor permission as space allows)	9
57-421	Exploded Ensemble	6
57-427	Advanced Seminar in Film Musicology	9
57-478	Survey of Historical Recording	6
57-622	Independent Study in Sound Recording Production	3
60-131	Foundations: Sculpture	10
85-385	Auditory Perception: Sense of Sound	9

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Audio Recording & Production concentration.

Composition Required Courses (13 courses, 85 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-161	Eurhythmics I (recommended co-requisite: 57-181)	3
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-49x	BXA Studio (4 semesters)	36
57-xxx	Major Ensemble (4 semesters)	24

Composition Electives (23 units minimum)

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Music Performance Required Courses (13 courses, 85 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-161	Eurhythmics I (recommended co-requisite: 57-181)	3
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-49x	BXA Studio (4 semesters)	36
57-xxx	Major Ensemble (4 semesters)	24

Music Performance Electives (23 units minimum)

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Sound Theory & Practice Required Courses (8 courses, 53 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-101	Introduction to Music Technology	6
or 57-171	Introduction to Music Technology (self-paced)	
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
18-090	Twisted Signals: Multimedia Processing for the Arts	10
57-421	Exploded Ensemble	6
57-911	Music Since 1945	9

Sound Theory & Practice Electives (55 units minimum)

Choose **55** units from:

57-153	Harmony II	9
or 57-150	Basic Harmony II	
57-182	Solfege II	3

or 57-186	Advanced Solfege II	
15-104	Introduction to Computing for Creative Practice	10
15-322	Introduction to Computer Music (prerequisite: 15-112)	9
33-114	Physics of Musical Sound	9
57-161	Eurhythmics I	3
57-162	Eurhythmics II	3
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-343	Music, Technology, and Culture	9
57-344	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music (prerequisite: 57-101 or 57-171)	6
57-358	Introduction to Electronic Music (with instructor permission as space allows)	9
57-438	Multitrack Recording	9
57-478	Survey of Historical Recording	6
57-616	Independent Study in Sound Studies	9

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Sound Theory & Practice concentration.

Free Electives

(approximately 2-7 courses, 15-63 units)

Take any Carnegie Mellon course. Many BHA students use their electives to broaden or deepen their concentrations. A maximum of 9 units of physical education and/or military science may be counted toward this requirement.

Bachelor of Science and Arts Degree Program

The Bachelor of Science and Arts (BSA) intercollege degree program combines the strengths of the College of Fine Arts (CFA) and the Mellon College of Science (MCS). This degree is designed for students who are gifted in both the fine arts and the natural sciences or mathematics, and who have the interest and the exceptional ability to pursue both disciplines simultaneously. Students choose their arts concentration from the following schools in CFA: Architecture, Art, Design, Drama or Music. Students choose their science concentration from among the departments in MCS: Biological Sciences, Chemistry, Environmental & Sustainability Studies, Mathematical Sciences, Neurobiology or Physics.

The BSA curriculum has three main components: general core requirements, fine arts concentration requirements and natural sciences/mathematics concentration requirements. Each student's course of study is structured so they can complete this rigorous program in four years.

Students receive extensive advising support. The academic advisors in the BXA Intercollege Degree Programs are the primary advisors and liaisons between CFA and MCS. Each student has two additional academic advisors: an advisor in the admitting school of CFA to guide their focus in the arts and an advisor in MCS to guide their focus in the sciences.

BSA Curriculum

	Units
I. BSA General Education	**129**
II. MCS Concentration	**114-145**
III. CFA Concentration	**108-130**
IV. Free Electives	**0-29**
Total BSA Degree Requirements	**380**

BSA General Education

(18 courses, 129 units minimum)

- Mathematics (2 courses, 20 units, 21-120 and 21-122 or 21-124 required)
- Science (3 courses, 31 units, 03-121, 09-105, and 33-121 or 33-151 required)
- First-year Courses (2 courses, 12 units, 76-101 and 99-101 required)
- ENGAGE (3 courses, 3 units)
- Cultural/Global Understanding (1 course, 9 units)
- Humanities and Social Sciences (2 courses, 18 units)
- BXA Required Courses (5 courses, 36 units, 52-190, 52-291, 52-392, 52-401, 52-402)

Technical Breadth Requirements (5 courses, 51 units)

As a 21st Century practicing scientist or mathematician, our graduates will work with others from a variety of technical backgrounds. Therefore, all of our students will be broadly trained within the technical fields of science and math. Students will fulfill this training by completing five (5) introductory technical courses in the Mellon College of Science at Carnegie Mellon University.

A student must take the five (5) courses listed below. AP/IB/Cambridge credit may be used to fulfill some of these requirements, but STEM electives must be taken at CMU or at another university for transfer credit to reach the total of five (5) Technical Breadth courses. A list of STEM electives can be found in the MCS general education requirements (p.).

Mathematics (2 courses, 20 units)

21-120	Differential and Integral Calculus	10
21-122	Integration and Approximation	10
or 21-124	Calculus II for Biologists and Chemists	

Science (3 courses, 31 units)

03-121	Modern Biology	9
09-105	Introduction to Modern Chemistry I	10
33-121	Physics I for Science Students	12
or 33-151	Matter and Interactions I	

Nontechnical Breadth Requirements (8 courses, 42 units)

MCS aspires for all of our undergraduates to leave our campus with a strong sense of personal integrity, social responsibility, ethics, working with diverse others, global engagement, and personal health and well-being. The following non-technical breadth requirements will require students to develop a personalized plan for their course selection and meta-curricular participation to maximize their CMU experience. Our graduates will be well trained to be life-long and life-wide learners that will lead the scientific community and the world at large.

All candidates for BSA degree must complete the following non-technical breadth requirements:

First-year Courses (2 courses, 12 units)

76-101	Interpretation and Argument -First-year	9
or 76-102	Advanced First Year Writing: Special Topics	
or 76-106 & 76-107 & 76-108	Writing about Literature, Art and Culture and Writing about Data and Writing about Public Problems	
All undergraduate students must complete the First-Year Writing requirement—the Department of English does not accept any Advanced Placement exemptions. This requirement can be completed in two different ways. Enroll in one of two full-semester courses 101 or 102 (by invitation only), 9 units, or enroll in two of three half-semester mini courses (back-to-back within a single semester) 106/107/108, 4.5 + 4.5 units. Course options and topics: www.cmu.edu/hss/english/first_year/index.html		
99-101	Core@CMU -Fall, First-year (section B; pass/no pass)	3

ENGAGE (3 courses, 3 units)

The ENGAGE courses are self-directed learning opportunities (using the MyCORE online platform) designed to enhance students' engagement with wellness and community service. Choose three courses from the list below:

38-110	ENGAGE in Service	1
38-230	ENGAGE in Wellness: Looking Inward	1
38-330	ENGAGE in Wellness: Looking Outward	1
38-430	ENGAGE in Wellness: Looking Forward	1

Cultural/Global Understanding (1 course, 9 units)

Cultural or global understanding course(s) may be taken at any time. Nine (9) or more units from the following group of courses will fulfill this requirement. Any student who finds an appropriate Carnegie Mellon course not on the list below that might fulfill this requirement should contact their academic advisor to review the course description to determine if it can be substituted. Cultural and global understanding courses that are taken while studying abroad can be used to fulfill this category. In addition, transfer courses will also be considered for this category. However, this course requirement cannot be satisfied with AP/IB/Cambridge exam credit.

57-173	Survey of Western Music History	9
57-306	World Music	9
70-342	Managing Across Cultures	9
76-217	Literature & Culture of the 20th and 21st Century	9
76-221	Books You Should Have Read By Now	9
76-232	Introduction to Black Literature	9
76-239	Introduction to Film Studies	9
76-241	Introduction to Gender Studies	9
76-386	Language & Culture	9
79-104	Global Histories	9
79-145	Genocide and Weapons of Mass Destruction	9
79-189	Democracy and History: Thinking Beyond the Self	9
79-201	Introduction to Anthropology	9
79-202	Flesh and Spirit: Early Modern Europe, 1400-1750	9
79-205	20th Century Europe	9
79-208	Witchcraft and Witch-Hunting	9
79-211	Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange	9
79-223	Mexico: From the Aztec Empire to the Drug War	9
79-227	Modern Africa: The Slave Trade to the End of Apartheid	9
79-229	The Origins of the Palestinian-Israeli Conflict, 1880-1948	9
79-230	The Arab-Israeli Conflict and Peace Process Through 1948 to Present	9
79-232	Arabian Peninsula Environmental History	9
79-234	Technology and Society	9
79-240	Development of American Culture	9
79-242	African American History: Reconstruction to the Present	9
79-244	Women in American History	9
79-245	Capitalism and Individualism in American Culture	9
79-250	Voting Rights: An Introduction	9
79-255	Modern Ireland: Politics and Culture from the Famine (1847) to Today	9
79-257	Germany and the Second World War	9
79-261	The Last Emperors: Chinese History and Society, 1600-1900	9
79-262	Modern China: From the Birth of Mao ... to Now	9
79-263	Mao and the Chinese Cultural Revolution	9
79-264	Tibet and China: History and Propaganda	9
79-265	Russian History: Game of Thrones	9
79-266	Russian History and Revolutionary Socialism	9
79-267	The Soviet Union in World War II: Military, Political, and Social History	9
79-275	Introduction to Global Studies	9
79-280	Coffee and Capitalism	9
79-283	Hungry World: Food and Famine in Global Perspective	9
79-328	Photographers and Photography Since World War II	9
79-343	Education, Democracy, and Civil Rights	9
79-345	Roots of Rock & Roll	9
79-350	Early Christianity	9
79-377	Food, Culture, and Power: A History of Eating	9
80-100	Introduction to Philosophy	9
80-101	Dangerous Ideas in Science and Society	9
80-250	Ancient Philosophy	9
80-251	Modern Philosophy	9
80-253	Continental Philosophy	9
80-254	Analytic Philosophy	9
80-255	Pragmatism: Making Ideas Work	9
80-276	Philosophy of Religion	9
82-xxx	Any course from Languages, Cultures, and Applied Linguistics	
84-380	US Grand Strategy	9
85-350	Psychology of Prejudice	9
85-352	Evolutionary Psychology	9

Humanities and Social Sciences (2 courses, 18 units)

To fulfill this requirement, students must complete a minimum of two (2) nontechnical courses totaling at least 18 units in the Tepper School of Business and/or the Dietrich College of Humanities and Social Sciences. Courses counted toward the Cultural/Global Understanding requirement, and 76-101, do not count toward this requirement.

Check our web site for courses from DC, CFA, and Tepper that may NOT be used (http://www.cmu.edu/mcs/undergrad/advising/hss-finearts/deletions.html) to satisfy this requirement because they are too technical in nature, plus a list of courses in other colleges (including SCS, CIT, Tepper, and Heinz College) that do satisfy (http://www.cmu.edu/mcs/undergrad/advising/hss-finearts/additions.html) this requirement.

BXA Required Courses (5 courses, 36 units)

BXA-specific courses give students the opportunity to integrate their areas of concentration by focusing on interdisciplinary approaches and arts-based research techniques.

52-190	BXA Seminar I: Building the Wunderkammer - Spring, First-year (mini-3)	4.5
52-291	BXA Seminar II: Transferring Knowledge -Spring, Sophomore year (mini-4)	4.5
52-392	BXA Seminar III: Deconstructing Disciplines - Spring, Junior year	9
52-401	BXA Seminar IV: Capstone Project Research -Fall, Senior year	9
52-402	BXA Seminar V: Capstone Project Production - Spring, Senior year	9

Mellon College of Science Concentration

(number of courses vary, 114-145 units)

BSA students declare one of the following concentrations, through consultation with their BXA advisor and the MCS concentration advisors. A completed MCS Concentration Declaration form must be approved by the concentration advisor and submitted to the BXA office, by spring mid-semester break of the student's first year.

- Biological Sciences (114 units)
- Chemistry (121 units)
- Environmental & Sustainability Studies (123 units)
- Mathematical Sciences (127 units)
- Neurobiology (114 units)
- Physics (145 units)
  Note: The BSA Physics concentration requires additional coursework totaling the degree requirements beyond 380 units.

BSA students who are admitted as freshmen are undeclared until they have met with a concentration advisor and have submitted their signed Declaration form. BSA students who are admitted through internal transfer must have chosen an MCS concentration at the time of their application (which serves as declaration). All BSA students wishing to change their MCS concentration at any time following the initial declaration must meet with the advisor of their intended concentration area to complete a new Declaration form.

Biological Sciences Concentration

(114 units minimum)

Biological Sciences Required Courses (11 courses, 96 units minimum)

03-201	Undergraduate Colloquium for Sophomores	2
03-220	Genetics - Fall, Sophomore year	9
03-231	Honors Biochemistry - Spring, Sophomore year	9

03-320	Cell Biology - Fall, Junior year	9
03-343	Experimental Techniques in Molecular Biology - Fall, Junior year	12
09-106	Modern Chemistry II	10
09-207	Techniques in Quantitative Analysis	9
09-208	Techniques for Organic Synthesis and Analysis	9
or 03-344	Experimental Biochemistry	
or 03-345	Experimental Cell and Developmental Biology	
or 03-346	Experimental Neuroscience	
09-217	Organic Chemistry I	9
09-218	Organic Chemistry II	9
33-122	Physics II for Biological Sciences & Chemistry Students	9

Biological Sciences Electives (2 courses, 18 units)

One course must be an advanced elective selected from 03-3xx or higher, excluding 03-445 and 03-545.

Chemistry Concentration

(118 units minimum)

Chemistry Required Courses (13 courses, 100 units)

09-106	Modern Chemistry II	10
09-219	Modern Organic Chemistry	10
09-220	Modern Organic Chemistry II	10
09-331	Modern Analytical Instrumentation	9
09-348	Inorganic Chemistry	10
09-221	Laboratory I: Introduction to Chemical Analysis	12
09-222	Laboratory II: Organic Synthesis and Analysis	12
09-321	Laboratory III: Molecular Design and Synthesis	12
or 09-323	Bioorganic Chemistry Laboratory	
09-201-09-202-09-301	Undergraduate Seminar I - Undergraduate Seminar II: Safety and Environmental Issues for Chemists - Undergraduate Seminar III	3
09-402	Undergraduate Seminar VI	3
33-122	Physics II for Biological Sciences & Chemistry Students	9

Note: Students who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an "A" grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

Advanced Chemistry Electives (2 courses, 18 units)

May be any upper level chemistry course, 09-3xx or higher, or Biochemistry I, 03-231 or 03-232, with the exception of 09-435 Independent Study, which can be used only by permission of the Director of Undergraduate Studies.

Environmental & Sustainability Studies Concentration

(123 units minimum)

Additional Required Courses (2 courses, 18 units minimum)

09-217	Organic Chemistry I	9
33-122	Physics II for Biological Sciences & Chemistry Students	9
or 33-142	Physics II for Engineering and Physics Students	

Core Courses (4 courses, 30 units)

24/09-381	Environmental Systems on a Changing Planet (co-req: 24-291/09-291)	12
66-236	Introduction to Environmental Ideas	9
66-506	Senior Capstone (Interdisciplinary Research: Capstone in ESS)	9

Earth and Environmental Science (1 course, 9 units)

Choose one course from the list below.

03-128	Biology for Life Special Topics (Section S, Tropical Ecology)	9
03-140	Ecology and Environmental Science	9
09-225	Climate Change: Chemistry, Physics and Planetary Science *	9
09-510	Chemistry and Sustainability *	9
09-524	Environmental Chemistry *	9
09-529	Introduction to Sustainable Energy Science *	9
09-538	Exposure and Risk Assessment for Environmental Pollutants *	9
33-226	Physics of Energy *	9

** Prerequisites from the BSA general education curriculum*

Global Course (1 course, 3 units)

99-xxx	Each semester, a new course is offered on Global themes, in partnership with University of Pittsburgh’s Global Studies Center.	3

Statistics and Data Science (1 course, 9 units)

36-xxx	Any Statistics Course	9

Political Economy (1 course, 9 units minimum)

Choose one course from the list below.

19-101	Introduction to Engineering and Public Policy	12
79-300	Controversial Topics in the History of American Public Policy	9
84-110	The Economics of Politics, Policy, and Technology	9
84-226	International Relations	9
84-325	Contemporary American Foreign Policy	9
88-344	Systems Analysis: Environmental Policy	9

Electives (5 courses, 45 units minimum)

Choose three MCS Electives and two DC Electives in consultation with the concentration advisor.

MCS Electives:

03-140	Ecology and Environmental Science	9
09-225	Climate Change: Chemistry, Physics and Planetary Science	9
09-510	Chemistry and Sustainability	9
09-524	Environmental Chemistry *	9
09-529	Introduction to Sustainable Energy Science	9
12-100	Exploring CEE: Infrastructure and Environment in a Changing World	12
12-201	Geology	9
19-101	Introduction to Engineering and Public Policy	12
19-425	Sustainable Energy for the Developing World	9
24-292	Renewable Energy Engineering	9
27-505	Exploration of Everyday Materials	9
33-226	Physics of Energy	9

DC Electives:

76-241	Introduction to Gender Studies	9
76-291	Getting Heard/Making a Difference	9
76-354	Watchdog Journalism	9
76-395	Science Writing *	9
76-450	Law, Culture, and the Humanities	9
79-201	Introduction to Anthropology	9
79-275	Introduction to Global Studies	9
79-278	How (Not) to Change the World	9
79-288	Bananas, Baseball, and Borders: Latin America and the United States	9
79-297	Technology and Work	9
79-331	Body Politics: Women and Health in America	9
79-372	The Rise and Fall of Pittsburgh Steel	6
79-377	Food, Culture, and Power: A History of Eating	9
79-379	Extreme Ethnography	9
79-383	The History of Capitalism	9
80-135	Introduction to Political Philosophy	9
80-244	Environmental Ethics	9
84-110	The Economics of Politics, Policy, and Technology	9
84-275	Comparative Politics	9
84-325	Contemporary American Foreign Policy	9
85-241	Social Psychology	9

** Additional prerequisites*

Mathematical Sciences Concentration

(127 units minimum)

Mathematical Sciences Required Courses (9 courses, 91 units minimum)

(Reasonable substitutions within the core program will be allowed.)

15-110	Principles of Computing	10
21-127	Concepts of Mathematics	12
or 21-128	Mathematical Concepts and Proofs	
21-228	Discrete Mathematics	9
21-241	Matrices and Linear Transformations	11
or 21-242	Matrix Theory	
21-259	Calculus in Three Dimensions	10
or 21-268	Multidimensional Calculus	
21-260	Differential Equations	9
or 21-261	Introduction to Ordinary Differential Equations	
or 33-231	Physical Analysis	
21-355	Principles of Real Analysis I	9
21-373	Algebraic Structures	9
33-142	Physics II for Engineering and Physics Students	12
or 33-152	Matter and Interactions II	

Mathematical Sciences Electives (2 courses, 18 units)

Two courses at the 21-300 level or above, or 21-270 or 21-292. Students with a Music concentration should take 21-469 Computational Introduction to Partial Differential Equations.

Mathematical Sciences, Computer Science, or Statistics Electives (2 courses, 18 units)

May be mathematical sciences courses at the 21-300 level or above, or 21-270 or 21-292; computer science courses at the 15-200 level or above; or statistics courses at the 36-300 level or above that have at least 36-225 as a prerequisite.

Neurobiology Concentration

(114 units minimum)

Neurobiology Required Courses (12 courses, 96 units)

03-161	Molecules to Mind	9
or 85-219	Foundations of Brain and Behavior	
03-201	Undergraduate Colloquium for Sophomores	2
03-220	Genetics - Fall, Sophomore year	9
03-231	Honors Biochemistry - Spring, Sophomore year	9
03-320	Cell Biology - Fall, Junior year	9
03-342	Introduction to Biological Laboratory Practices - Fall, Junior year	1
03-343	Experimental Techniques in Molecular Biology - Fall, Junior year	12
03-362	Cellular Neuroscience	9
03-363	Systems Neuroscience	9
09-217	Organic Chemistry I	9
33-122	Physics II for Biological Sciences & Chemistry Students	9
85-211	Cognitive Psychology	9

Neurobiology Electives (2 courses, 18 units)

One course must be an advanced elective selected from 03-3xx or higher.

Physics Concentration (145 units minimum)

Physics Required Courses (16 courses, 127 units)

21-259	Calculus in Three Dimensions	10
33-104	Experimental Physics	9
33-142	Physics II for Engineering and Physics Students	12
or 33-152	Matter and Interactions II	
33-201	Physics Sophomore Colloquium I -Fall	2
33-202	Physics Sophomore Colloquium II -Spring	2
33-211	Physics III: Modern Essentials	10
33-228	Electronics I	10
33-231	Physical Analysis	10
33-232	Mathematical Methods of Physics	10
33-234	Quantum Physics	10
33-301	Physics Upperclass Colloquium I -Fall	1
33-302	Physics Upperclass Colloquium II -Spring	1
33-331	Physical Mechanics I	10
33-338	Intermediate Electricity and Magnetism I	10
33-340	Modern Physics Laboratory	10
33-341	Thermal Physics I	10

Qualifying Physics Electives (2 courses, 18 units)

Two 33-xxx qualifying physics elective courses (http://coursecatalog.web.cmu.edu/schools-colleges/melloncollegeofscience/departmentofphysics/#physicselectivestextcontainer) pre-approved by the Physics Department. 33-114 Physics of Musical Sound is highly recommended for students with a Music concentration.

COLLEGE OF FINE ARTS CONCENTRATION

(number of courses vary, 108-130 units minimum)

BSA students choose one of the following concentrations:

- Architecture (108 units)
- Art (114 units)
- Design (108 units)
- Drama (130 units)
- Music (108 units)

Architecture Concentration

(108 units minimum)

Architecture Required Courses (9 courses, 57 units minimum)

48-100	Architecture Design Studio: POIESIS STUDIO 1 - Fall, Freshman or Sophomore year	10-15
or 48-095	Spatial Concepts for Non-Architecture Majors	
48-104	Shop Skills -Fall, Freshman year	2
62-104	Design Ethics & Social Justice in Architecture - Fall, Freshman or Sophomore year	3
62-122	Digital Media I -Fall, Freshman year	6
62-125	Drawing I -Fall, Freshman year	6
62-123	Digital Media II -Spring, Freshman year	6
62-126	Drawing II -Spring, Freshman year	6
48-240	History of World Architecture, I -Spring, Freshman year	9
48-241	History of Modern Architecture -Fall, Sophomore year	9

Architecture Electives (51 units minimum)

A minimum of **51** additional Architecture units must be approved by the Architecture advisor. A list of these selected courses must be filed in the BXA office. 48-025 First Year Seminar: Architecture Edition I (3 units) is recommended in fall of the first year.

Art Concentration

(114 units minimum)

First-Year Seminar (1 course, 6 units)

60-104	Foundations: Art First-Year Seminar	6

Foundation Studios (3 courses, 30 units)

Complete three courses:

60-110	Foundations: Time-Based Media	10
60-120	Foundations: Digital Media	10
60-131	Foundations: Sculpture	10
60-135	Foundations: Sculpture II	10
60-150	Foundations: Drawing	10
60-170	Foundations: Paint/Print	10

Intermediate Studios (3 courses, 30 units)

Complete three courses:

60-2xx	Intermediate Studio Elective	10
60-2xx	Intermediate Studio Elective	10
60-2xx	Intermediate Studio Elective	10

Advanced Studios (3 courses, 30 units)

Students may take courses in any media area (ETB, SIS, CP or DP3). They may take all courses in one media area if a focus is desired. With approval from the Art advisor, BXA students can take an additional intermediate studio in lieu of an advanced studio to increase breadth.

Complete three courses:

60-401/402	Senior Studio	10
60-403	Senior Critique Seminar	10
Advanced Electronic and Time-Based Work (ETB) (course numbers 60-410 through 60-429) *		10
Advanced Sculpture, Installation and Site-Work (SIS) (course numbers 60-430 through 60-447) *		10
Advanced Contextual Practice (CP) (course numbers 60-448 through 60-449) *		10
Advanced Drawing, Painting, Print Media and Photography (DP3) (course numbers 60-450 through 60-498) *		10
60-499	Studio Independent Study (one only)	10

** Courses offered intermittently; speak with a BXA advisor to determine course availability.*

Critical Studies (2 courses, 18 units)

60-107	Foundations: Critical Studies -Spring	9
60-3xx	Critical Studies Elective	9

Review Requirement (1 required review, 0 units)

Complete required review:

60-200	Sophomore Review -Spring (pass/no pass)	0

Design Concentration

(108 units minimum)

Note: BXA design only considers internal transfer applicants currently enrolled in Design.

Design Required Courses (16 courses, 98 units)

51-101	Studio: Survey of Design -Fall, First-year	10
51-121	Visualizing -Fall, First-year	10
51-175	Design Studies: Place -Fall, First-year (mini-1)	5
51-177	Design Studies: Histories -Fall, First-year (mini-2)	5
51-102	Design Lab -Spring, First-year	10
51-122	Collaborative Visualizing -Spring, First-year	10
51-176	Design Studies: Futures -Spring, First-year (mini-3)	5
51-178	Design Studies: Experience -Spring, First-year (mini-4)	5
51-277	Design Studies: Systems -Fall, Sophomore year (mini-1)	5
51-279	Design Studies: Cultures -Fall, Sophomore year (mini-2)	5
51-282	Design Studies: Persuasion -Spring, Sophomore year (mini-3)	5
51-284	Design Studies: Power -Spring, Sophomore year (mini-4)	5
Choose Two Studios -Fall, Sophomore year:		4.5+4.5
51-225	Communications Studio I: Understanding Form & Context	4.5
or 51-245	Products Studio I: Understanding Form & Context	
or 51-265	Environments Studio I: Understanding Form & Context	
Choose Two Corresponding Labs -Fall, Sophomore year:		4.5+4.5
51-227	Prototyping Lab I: Communications	4.5
or 51-247	Prototyping Lab I: Products	
or 51-267	Prototyping Lab I: Environments	

Design Electives (10 units)

A minimum of **10** additional Design units must be approved by the Design advisor. A list of these selected courses must be filed in the BXA office.

Drama Concentration

(130 units minimum)

Options available in the following areas: 1) Design, 2) Dramaturgy, 3) Production Technology and Management

Note: BXA design only considers internal transfer applicants currently enrolled in Drama design. BXA dramaturgy only considers internal transfer applicants in the fall semester for spring enrollment, unless currently enrolled in Drama dramaturgy. BXA PTM only considers internal transfer applicants currently enrolled in Drama PTM.

Design/PTM Required Courses (10 courses, 75 units)

54-169	Studiocraft 1 -Fall, First-year	13
54-151	Stagecraft -Fall, First-year	6
54-159	Production Practicum -Fall, First-year	6
54-171	Basic Design 1 -Fall, First-year	6
54-170	Studiocraft 2 -Spring, First-year	8
54-152	Stagecraft -Spring, First-year	12
54-158	Production Planning -Spring, First-year	6
54-177	Foundations of Drama I -Spring, First-year or later if needed	6
54-281	Foundations of Drama II	6
54-381	Special Topics: Feminist Theatre	6

Design/PTM Required Courses (55 units minimum)

A minimum of **55** additional Design/PTM units taken in the sophomore year or later must be approved by the Design/PTM faculty area chair. A list of these selected courses must be filed in the BXA office.

Dramaturgy Required Courses (13 courses, 80 units)

54-177	Foundations of Drama I -Fall, First-year	6
54-109	Dramaturgy 1: Approaches to Text -Fall, First-year	9
54-284	Fundamentals of Directing -Fall, First-year	6
54-200	Dramaturgy Forum -Fall, First-year	1
54-159	Production Practicum -Fall or Spring, First-year	6
54-281	Foundations of Drama II -Spring, First-year	6
54-184	Dramaturgy 2: Introduction to Production Dramaturgy -Spring, First-year	9
54-200	Dramaturgy Forum -Spring, First-year	1
54-117	Design Collaboration Project -Spring, First-year	3
54-241	Dramaturgy 3: Dramaturgy in Translation -Fall, Sophomore year	9
54-256	Dramaturgy 4: New Play Dramaturgy -Spring, Sophomore year	9
54-363	Dramaturgy 5 -Fall, Junior year	9
54-381	Special Topics: Feminist Theatre	6

Dramaturgy Electives (50 units minimum)

A minimum of **50** additional Dramaturgy units taken in the sophomore year or later must be approved by the Dramaturgy faculty area chair. A list of these selected courses must be filed in the BXA office.

Music Concentration

(108 units minimum)

Options available in the following areas: 1) Audio Recording & Production, 2) Composition, 2) Music Performance (instrumental, organ, piano, voice), 4) Sound Theory & Practice

Note: BXA music performance only considers internal transfer applicants in the spring semester for fall enrollment, unless currently enrolled in Music performance.

Audio Recording & Production Required Courses (8 courses, 49 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-101	Introduction to Music Technology	6
or 57-171	Introduction to Music Technology (self-paced)	
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-438	Multitrack Recording	9

Audio Recording & Production Electives (59 units minimum)

Choose **59** units from:

57-153	Harmony II	9
or 57-150	Basic Harmony II	
57-182	Solfege II	3
or 57-186	Advanced Solfege II	
10-301	Introduction to Machine Learning	12
15-104	Introduction to Computing for Creative Practice	10
15-213	Introduction to Computer Systems	12
15-322	Introduction to Computer Music	9
18-090	Twisted Signals: Multimedia Processing for the Arts	10
33-114	Physics of Musical Sound	9
54-166	Introduction to Sound Design for Theatre	6
54-666	Production Audio (section B)	4
57-161	Eurhythmics I	3
57-162	Eurhythmics II	3
57-344	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music	6
57-358	Introduction to Electronic Music (with instructor permission as space allows)	9
57-421	Exploded Ensemble	6
57-427	Advanced Seminar in Film Musicology	9
57-478	Survey of Historical Recording	6
57-622	Independent Study in Sound Recording Production	3
60-131	Foundations: Sculpture	10
85-385	Auditory Perception: Sense of Sound	9

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Audio Recording & Production concentration.

Composition Required Courses (13 courses, 85 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-161	Eurhythmics I (recommended co-requisite: 57-181)	3
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-49x	BXA Studio (4 semesters)	36
57-xxx	Major Ensemble (4 semesters)	24

Composition Electives (23 units minimum)

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Music Performance Required Courses (13 courses, 85 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-161	Eurhythmics I (recommended co-requisite: 57-181)	3
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-49x	BXA Studio (4 semesters)	36
57-xxx	Major Ensemble (4 semesters)	24

Music Performance Electives (23 units minimum)

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Sound Theory & Practice Required Courses (8 courses, 53 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-101	Introduction to Music Technology	6
or 57-171	Introduction to Music Technology (self-paced)	
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
18-090	Twisted Signals: Multimedia Processing for the Arts	10
57-421	Exploded Ensemble	6
57-911	Music Since 1945	9

Sound Theory & Practice Electives (55 units minimum)

Choose **55** units from:

57-153	Harmony II	9
or 57-150	Basic Harmony II	
57-182	Solfege II	3
or 57-186	Advanced Solfege II	
15-104	Introduction to Computing for Creative Practice	10
15-322	Introduction to Computer Music (prerequisite: 15-112)	9
33-114	Physics of Musical Sound	9
57-161	Eurhythmics I	3
57-162	Eurhythmics II	3
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-343	Music, Technology, and Culture	9
57-344	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music (prerequisite: 57-101 or 57-171)	6
57-358	Introduction to Electronic Music (with instructor permission as space allows)	9
57-438	Multitrack Recording	9
57-478	Survey of Historical Recording	6
57-616	Independent Study in Sound Studies	9

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Sound Theory & Practice concentration.

Free Electives

(approximately 0-3 courses, 0-29 units)

Take any Carnegie Mellon course. A maximum of 9 units of physical education and/or military science may be counted toward this requirement. Physical education and military science courses will not be calculated in a student's QPA.

Engineering and Arts Additional Major

The Engineering and Arts (EA) additional major combines the strengths of the College of Fine Arts (CFA) and the College of Engineering (ENG). This additional major provides students with formal practice and training in the creative arts that is more robust than a minor, as well as the foundation of interdisciplinary research to accomplish the integration of their interests. Students who currently have a primary major in engineering, choose their arts concentration from the following schools in CFA: Architecture, Art, Drama or Music.

The EA curriculum has two main components: BXA requirements and fine arts concentration requirements. Each student's course of study is structured so it can be completed alongside their primary engineering major.

Students receive extensive advising support. The academic advisors in the BXA Intercollege Degree Programs are the advisors and liaisons between CFA and Engineering. Each student has two additional academic advisors: an advisor in the admitting school of CFA to guide their focus in the arts and their primary advisor in Engineering to guide their full major in engineering.

EA Curriculum

	Units
I. BXA Requirements	**36**
II. CFA Concentration	**108-130**
Total EA Additional Major Requirements	**144-166**

BXA Requirements

BXA Required Courses (5 courses, 36 units)

BXA-specific courses give students the opportunity to integrate their areas of concentration by focusing on interdisciplinary approaches and arts-based research techniques.

52-190	BXA Seminar I: Building the Wunderkammer - Spring, First-year (mini-3)	4.5
52-291	BXA Seminar II: Transferring Knowledge -Spring, Sophomore year (mini-4)	4.5
52-392	BXA Seminar III: Deconstructing Disciplines - Spring, Junior year	9
52-401	BXA Seminar IV: Capstone Project Research -Fall, Senior year	9
52-402	BXA Seminar V: Capstone Project Production - Spring, Senior year	9

COLLEGE OF FINE ARTS CONCENTRATION

(number of courses vary, 108-130 units minimum)

EA students choose one of the following concentrations:

- Architecture (108 units)
- Art (114 units)
- Drama (130 units)
- Music (108 units)

Architecture Concentration

(108 units minimum)

Architecture Required Courses (9 courses, 57 units minimum)

48-100	Architecture Design Studio: POIESIS STUDIO 1 - Fall, First-year or Sophomore year	10-15
or 48-095	Spatial Concepts for Non-Architecture Majors	
48-104	Shop Skills -Fall, First-year	2
62-104	Design Ethics & Social Justice in Architecture - Fall, First-year or Sophomore year	3
62-122	Digital Media I -Fall, First-year	6
62-125	Drawing I -Fall, First-year	6
62-123	Digital Media II -Spring, First-year	6
62-126	Drawing II -Spring, First-year	6
48-240	History of World Architecture, I -Spring, First-year	9
48-241	History of Modern Architecture -Fall, Sophomore year	9

Architecture Electives (51 units minimum)

A minimum of **51** additional Architecture units must be approved by the Architecture advisor. A list of these selected courses must be filed in the BXA office. 48-025 First Year Seminar: Architecture Edition I (3 units) is recommended in fall of the first year.

Art Concentration

(114 units minimum)

First-Year Seminar (1 course, 6 units)

60-104	Foundations: Art First-Year Seminar	6

Foundation Studios (3 courses, 30 units)

Complete three courses:

60-110	Foundations: Time-Based Media	10
60-120	Foundations: Digital Media	10
60-131	Foundations: Sculpture	10
60-135	Foundations: Sculpture II	10
60-150	Foundations: Drawing	10
60-170	Foundations: Paint/Print	10

Intermediate Studios (3 courses, 30 units)

Complete three courses:

60-2xx	Intermediate Studio Elective	10
60-2xx	Intermediate Studio Elective	10
60-2xx	Intermediate Studio Elective	10

Advanced Studios (3 courses, 30 units)

Students may take courses in any media area (ETB, SIS, CP or DP3). They may take all courses in one media area if a focus is desired. With approval from the Art advisor, BXA students can take an additional intermediate studio in lieu of an advanced studio to increase breadth.

Complete three courses:

60-401/402	Senior Studio	10
60-403	Senior Critique Seminar	10
Advanced Electronic and Time-Based Work (ETB) (course numbers 60-410 through 60-429) *		10
Advanced Sculpture, Installation and Site-Work (SIS) (course numbers 60-430 through 60-447) *		10
Advanced Contextual Practice (CP) (course numbers 60-448 through 60-449) *		10
Advanced Drawing, Painting, Print Media and Photography (DP3) (course numbers 60-450 through 60-498) *		10
60-499	Studio Independent Study (one only)	10

* *Courses offered intermittently; speak with a BXA advisor to determine course availability.*

Critical Studies (2 courses, 18 units)

60-107	Foundations: Critical Studies -Spring	9
60-3xx	Critical Studies Elective	9

Review Requirement (1 required review, 0 units)

Complete required review:

60-200	Sophomore Review -Spring (pass/no pass)	0

Drama Concentration

(130 units minimum)

Option available in the following area: 1) Dramaturgy

Note: EA dramaturgy only considers applicants in the fall semester for spring enrollment.

Dramaturgy Required Courses (13 courses, 80 units minimum)

54-177	Foundations of Drama I -Fall, First-year	6
54-109	Dramaturgy 1: Approaches to Text -Fall, First-year	9
54-284	Fundamentals of Directing -Fall, First-year	6
54-200	Dramaturgy Forum -Fall, First-year	1
54-159	Production Practicum -Fall or Spring, First-year	6
54-281	Foundations of Drama II -Spring, First-year	6
54-184	Dramaturgy 2: Introduction to Production Dramaturgy -Spring, First-year	9
54-200	Dramaturgy Forum -Spring, First-year	1
54-117	Design Collaboration Project -Spring, First-year	3
54-241	Dramaturgy 3: Dramaturgy in Translation -Fall, Sophomore year	9
54-256	Dramaturgy 4: New Play Dramaturgy -Spring, Sophomore year	9
54-363	Dramaturgy 5 -Fall, Junior year	9
54-381	Special Topics: Feminist Theatre	6

Dramaturgy Required Courses (50 units minimum)

A minimum of **50** additional Dramaturgy units taken in the sophomore year or later must be approved by the Dramaturgy faculty area chair. A list of these selected courses must be filed in the BXA office.

Music Concentration

(108 units minimum)

Options available in the following areas: 1) Audio Recording & Production, 2) Composition, 2) Music Performance (instrumental, organ, piano, voice), 4) Sound Theory & Practice

Note: EA music performance only considers applicants in the spring semester for fall enrollment.

Audio Recording & Production Required Courses (8 courses, 49 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-101	Introduction to Music Technology	6
or 57-171	Introduction to Music Technology (self-paced)	
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-438	Multitrack Recording	9

Audio Recording & Production Electives (59 units minimum)

Choose **59** units from:

57-153	Harmony II	9
or 57-150	Basic Harmony II	
57-182	Solfege II	3
or 57-186	Advanced Solfege II	
10-301	Introduction to Machine Learning	12
15-104	Introduction to Computing for Creative Practice	10
15-213	Introduction to Computer Systems	12
15-322	Introduction to Computer Music	9
18-090	Twisted Signals: Multimedia Processing for the Arts	10
33-114	Physics of Musical Sound	9
54-166	Introduction to Sound Design for Theatre	6
54-666	Production Audio (section B)	4
57-161	Eurhythmics I	3
57-162	Eurhythmics II	3
57-344	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music	6
57-358	Introduction to Electronic Music (with instructor permission as space allows)	9
57-421	Exploded Ensemble	6
57-427	Advanced Seminar in Film Musicology	9
57-478	Survey of Historical Recording	6
57-622	Independent Study in Sound Recording Production	3
60-131	Foundations: Sculpture	10
85-385	Auditory Perception: Sense of Sound	9

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Audio Recording & Production concentration.

Composition Required Courses (13 courses, 85 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-161	Eurhythmics I (recommended co-requisite: 57-181)	3
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-49x	BXA Studio (4 semesters)	36
57-xxx	Major Ensemble (4 semesters)	24

Composition Electives (23 units minimum)

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Music Performance Required Courses (13 courses, 85 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-161	Eurhythmics I (recommended co-requisite: 57-181)	3
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
57-49x	BXA Studio (4 semesters)	36
57-xxx	Major Ensemble (4 semesters)	24

Music Performance Electives (23 units minimum)

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Sound Theory & Practice Required Courses (8 courses, 53 units)

57-152	Harmony I	9
or 57-149	Basic Harmony I	
57-101	Introduction to Music Technology	6
or 57-171	Introduction to Music Technology (self-paced)	
57-181	Solfege I	3
or 57-180	Basic Solfege I	
or 57-185	Advanced Solfege I	
57-173	Survey of Western Music History (co-requisite: 57-188)	9
57-188	Repertoire and Listening for Musicians	1
18-090	Twisted Signals: Multimedia Processing for the Arts	10
57-421	Exploded Ensemble	6
57-911	Music Since 1945	9

Sound Theory & Practice Electives (55 units minimum)

Choose **55** units from:

57-153	Harmony II	9
or 57-150	Basic Harmony II	
57-182	Solfege II	3
or 57-186	Advanced Solfege II	
15-104	Introduction to Computing for Creative Practice	10
15-322	Introduction to Computer Music (prerequisite: 15-112)	9
33-114	Physics of Musical Sound	9
57-161	Eurhythmics I	3
57-162	Eurhythmics II	3
57-337	Sound Recording	6
57-338	Sound Editing and Mastering	6
57-343	Music, Technology, and Culture	9
57-344	Experimental Sound Synthesis	9
57-347	Electronic and Computer Music (prerequisite: 57-101 or 57-171)	6
57-358	Introduction to Electronic Music (with instructor permission as space allows)	9
57-438	Multitrack Recording	9
57-478	Survey of Historical Recording	6
57-616	Independent Study in Sound Studies	9

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Sound Theory & Practice concentration.

Academic Policies

Professional and Community Standards

As a condition of enrollment BXA, and as a student in the College of Fine Arts, we expect you to positively contribute to the community in order to fully engage in the intellectual life at CFA. Classrooms, studios, rehearsal and performance spaces, exhibition venues and off-campus curricular destinations are safe spaces for expression and self-identification. Students are expected to treat everyone with respect, regardless of race, country of origin, gender identity and expression, sexual orientation, disability, physical appearance, age, religion, political affiliation or marital status. Lack of respect and harassment includes offensive comments related to any protected personal characteristic, deliberate intimidation, sustained disruption of speech, inappropriate physical contact and unwelcome sexual attention. Violations of this agreement are subject to a response to be determined by the BXA Director and CFA Associate Deans.

Academic Standards and Actions

Grading Practices

Grades given to record academic performance in the College of Fine Arts are detailed in the catalog section entitled "Undergraduate Academic Regulations." All courses taught by the schools in the College of Fine Arts follow the standard letter grade system of the university. Responsibility for the grade given to the student rests entirely with the instructor and the school concerned. A permanent grade may not be raised by taking a second examination or evaluation. Students who wish to repeat a course already passed must obtain approval from the Dean of the College. At the time of approval, the Dean will decide in the light of circumstances whether the new grade or the old grade will be the official grade used as the computing factor for honors. Both grades, however, will appear on the official transcript.

Grade Appeals

In the event a student believes an assigned grade is incorrect or not appropriate, the student may follow the university processes outlined in the Word to seek prompt and equitable resolution of the matter. All appeals are initially addressed to the instructor of record. If unresolved, the appeal can be forwarded to the Head of School (or department head if outside of CFA). https://www.cmu.edu/student-affairs/theword/academic/appeal-of-grades-and-academic-actions.html

Monitoring Degree Progress

The College of Fine Arts seeks to support each of our students on their pathway towards graduation. Thus, we review each student’s academic performance and progress towards degree at the close of each semester. Academic actions are designed to notify a student of specific academic and graduation requirements, outline goals for completion, and identify avenues of support. Academic actions are opportunities for students to reflect, grow, and get connected with appropriate campus resources to help them succeed.

To stay on track for graduation, each student is expected to complete a minimum of 36* units each semester, have both a semester and cumulative QPA of at least 2.0, and make adequate progress towards their declared degree. Adequate progress requires that at least 80% of their semester units are passed, that a student registers for their program’s expected coursework, and that they have met the minimum grades required to progress in sequential coursework. BXA students have additional academic requirements to meet a minimum threshold of D or C in certain academic courses, per their specific academic program curriculum.

If a student’s academic record falls below these standards, they receive an academic action. These actions are assigned based on the most recent semester under review as well as a cumulative review of a student’s performance to date. Each program will recommend students for notification and the CFA Academic Advisory Committee will finalize these decisions. The CFA Dean’s office will then disseminate the academic action letters directly to the students and their advisors via their CMU email. To best support academic success, a student placed on an academic action is not permitted to overload, undertake independent studies, or study abroad until they return to good standing. (See school/program handbook for additional restrictions and specifications.)

Incomplete grades will be conditionally actioned by the default grades until the student completes the missing coursework. If the student does not complete their missing coursework by the faculty deadline agreed upon, their default grade and action will become permanent.

* *Students approved for Part Time Status through the Office of Disability Resources will work with their Program’s administration to determine the minimum number of units needed to remain in Good Standing.*

Academic Notifications

A preliminary email from an academic advisor may alert a student of an issue that will impede their degree progress if left unresolved (aka re-taking a general education requirement or falling behind on registering for required courses etc.) If the student meets new actionable criteria in the following semesters, they may be assigned an academic action.

The College of Fine Arts administers academic action letters to help all students stay abreast of their progress towards degree and to ultimately support their path to graduation. If a student falls below the outlined academic standards listed above (earn a minimum 2.0 semester and cumulative QPA and make adequate degree progress), they will receive an academic action letter at the close of that semester. If problems persist, they will receive escalating actions as listed below. However, once a student resumes adequate degree progress and earns a semester and cumulative QPA of at least 2.0, they are returned to Good Academic Standing and will remain in good standing so long as the academic standards are still being met.

Academic Concern

Academic Concern letters notify the student of a concerning academic performance issue(s) and suggests that the student take immediate steps to correct the cause of the difficulty. It is the first academic action administered to students who fall behind one or more of the degree standards. A student will remain on Academic Concern for the length of the next semester (Fall or Spring). Note that Academic Concern is an internal notification and will not appear on a student’s academic transcript. If the student does not meet these standards in future semesters, they may be assigned a successive academic action.

Academic Warning

A student will be placed on Academic Warning for continued poor performance, or for continued failure to meet the requirements of their declared degree path. Academic Warning is the second level academic action administered to students who fall behind at least one of the degree standards for two or more semesters. A student will remain on this action for the length of the next semester (Fall or Spring). Again, Academic Warning is an internal notification and will not appear on a student’s academic transcript. One or more previous actions are needed to qualify. If the student does not meet these standards in future semesters, they may be assigned a successive academic action.

Academic Suspension

Academic Suspension is a required, temporary leave from the university. It is administered to students who fall behind at least one of the degree standards for three or more semesters. (Two or more academic actions must proceed a suspension). An Academic Suspension is intended to allow the student time to address any issues impeding or affecting their performance in order to progress towards meeting the academic standards of their declared degree path. The student is required to temporarily withdraw from the university for a specific period as defined in their suspension letter.

The College of Fine Arts remains committed to students during these periods of temporary leave and continues to connect them to College and University level supports while they are away. Return from suspension is subject to the conditions specified in the suspension letter and approval of the CFA Dean’s office. Details concerning associated restrictions can be found at: https://www.cmu.edu/policies/student-and-student-life/suspension-required-withdrawal-policy.html.

Final Academic Warning

Following a Suspension, students will be placed on Final Academic Warning during their initial semester of return.

Academic Drop

An Academic Drop is the final academic notification and is only administered after a substantial pattern of academic difficulty. Four or more semesters below standards, including a Suspension, are needed prior to an Academic Drop.

This action terminates the student’s enrollment in their current School/Program but is not intended to prejudice admission to another academic program within Carnegie Mellon University, or to another institution. If a student has earned a cumulative grade point average of at least a 2.0, they may still apply for internal transfer within CMU–noting that the student must successfully transfer prior to resuming study at Carnegie Mellon.

Appeal of Academic Actions

Students have the right to appeal Academic Action decisions to the CFA Dean. All appeals must be received in writing by the deadline printed in the academic standing notification (within 10 days of the dated letter). If a student's initial appeal is denied they may choose to further their appeal to the Provost's Office in writing by the deadline printed in the appeal response (within 5 days of the dated letter). Additional information about appealing an academic action decision is found in The Word: Student Handbook (https://www.cmu.edu/student-affairs/theword/academic/appeal-of-grades-and-academic-actions.html).

Disabilities

Students with a learning disability or a physical disability are encouraged to email access@andrew.cmu.edu. The circumstances will remain confidential to the extent desired. The university has a formal procedure for documenting disabilities, notifying advisors and faculty, and making arrangements to utilize university resources in support of expressed needs, but will take no action until contacted by the student. The BXA academic advisors will work with the student to coordinate assistance. Please note that requests for accommodations are not retroactive; you must ask that accommodation requests be put in place before you anticipate needing them.

Grading Policies

University grading policies may vary depending on the particular school/department. Please consult the Undergraduate Academic Regulations (http://coursecatalog.web.cmu.edu/servicesandoptions/undergraduateacademicregulations/).

Intercollege Deans' List

Students who earn 36 graded units (no "pass/no pass" grades) with a grade point average of 3.5 or higher, no "incompletes" and "no grades" qualify for BCSA, BESA, BHA or BSA Deans' List. The BXA Intercollege Deans' List Honors are posted online each semester.

Intercollege Honors

BXA students who successfully complete a BXA Capstone Project under the guidance of a faculty member will graduate with BCSA, BESA, BHA, BSA or EA Intercollege Honors if all of the following conditions are met:

- grade of "A" achieved in 62-401 and 62-402;
- overall QPA of 3.25 or higher;
- publicly present research results.

As a citizen of two colleges, a BXA student also has the opportunity to graduate with CFA College Honors, DC College Honors, ENG College Honors, MCS College Honors and SCS College Honors. These particular honors are defined by each college. BXA students will receive honors color cords during Commencement Weekend.

University Honors

Students who graduate with an overall QPA of 3.5 or higher will graduate with University Honors. Students will receive an honors medallion during Commencement Weekend.

Internal Transfer/Additional Major Process

For current Carnegie Mellon students who wish to apply to a BXA program, an internal transfer and additional major (EA) application process takes place in both the fall and spring semester. Applications are available online and are reviewed by a committee of BCSA, BESA, BHA, BSA and EA associate deans and advisors in October and in March. However, certain concentrations consider applications only once a year or certain concentrations only consider applicants currently enrolled in the same major as the intended concentration; please consult with a BXA advisor for guidance on scheduling your application.

All students applying for internal transfer should meet with their current advisor, a BXA advisor and an advisor in their target area, as well as take preliminary coursework in their target area and complete their first semester before applying. For all concentrations, there are required courses that must be taken before an application will be considered; please consult with a BXA advisor for guidance on scheduling these courses. Additionally, a cumulative QPA of 3.0 is required for all BXA programs and students must complete their first semester at Carnegie Mellon before applying for internal transfer.

Current BXA students who wish to change their BXA program (e.g. BHA to BCSA) or change their CFA concentration (e.g BHA architecture to BHA art) or delineated options within CFA concentrations (e.g. music performance to music composition) must apply for that change through the internal transfer process. Current BESA, BHA and BSA students who wish to change their academic college concentration after declaring (e.g. BHA creative writing to BHA psychology, BSA physics to BSA mathematical sciences) or delineated options within their academic college concentration (e.g. BESA chemical engineering to BESA mechanical engineering) after declaring must submit a new BESA ENG/BHA DC/BSA MCS Concentration Declaration form for approval of that change. Current BXA students seeking internal transfer out of BXA into another college program must apply and meet entry requirements to that program. Students who do not remain in BCSA can only return to their original major.

Study Abroad

Studying abroad is encouraged to broaden BXA students' interdisciplinary experiences through traditional and non-traditional study abroad, from coursework and artistic studios to for-credit internships, volunteer service and research opportunities.

Courses taken while studying abroad may count toward your BXA concentration requirements, your general education requirements or your free electives. Studying abroad should not delay your graduation, as long as you work with your study abroad advisor and your BXA advisor to plan the most appropriate courses.

The timing and length of program are important considerations while planning. Due to required BXA coursework, students should avoid studying abroad in their last three semesters (junior spring, senior fall/spring). Spending an entire year abroad is not typically possible for BXA students without intending to take an additional semester at Carnegie Mellon. Many students study abroad during the spring of their sophomore year or the fall semester of their junior year, as well during the summer, and over winter and spring breaks. Talk to your BXA academic advisor early in your academic career to identify the best time for study abroad.

When studying abroad, students are still enrolled at Carnegie Mellon. A student never takes a leave of absence to study abroad. Prior to studying abroad, all students must attend a required pre-departure orientation offered by the Office of International Education (OIE).

Students must also complete a Study Abroad Transfer Credit (SATC) form prior to departure for study abroad, which must be signed after completion by the BXA advisor. The SATC will guarantee transfer credit for courses taken abroad, and is filled out by the corresponding departments to the coursework being transferred. Unlike regular transfer credit, there is no limit to the number of courses transferable from study abroad, but there may exist stricter limits on the use of coursework to fulfill concentration or general education requirements.

Students will receive credit for courses for which they receive a grade of "C" or better. However, grades received abroad do not count toward a student's Carnegie Mellon University QPA.

Students who are on academic action may have restrictions from participating in some school, college, and university activities, including eligibility for study abroad.

Transfer Credit

Once a BXA student enrolls at Carnegie Mellon University as a degree candidate, they may transfer a maximum of five courses from another institution (excepting official study abroad programs through the CMU Office of International Education) for credit towards their BXA degree. This applies to courses taken at other institutions in the United States, as well as courses taken internationally in the student's home country.

Individual departments may impose stricter limits regarding the number or type of courses students propose to take elsewhere to fulfill requirements. Some departments may not accept transfer credit from online courses.

Students must have prior approval to transfer courses from their BXA advisor, as well as concentration advisors, to use coursework towards requirements. To receive permission, students must provide course information (syllabi) to the corresponding department for evaluation of appropriate credit. When the course is finished, official transcripts must be sent to Carnegie Mellon University before credit will be recorded.

Transfer courses must be taken for a letter grade and students must earn a C (2.00) or above (B or above at a community college). Transfer credit is not factored into a student's CMU QPA.

The following courses must be taken at CMU and cannot be transferred in:

- First-Year Writing Requirement Course (76-101, 76-102, 76-106/7/8)
- Humanities (79-104, 79-145, 79-189)
- 36-200: Statistical Reasoning (AP credit only)
- 99-101: Core@CMU

Students currently on university suspension are permitted to take no more than three courses per semester at another institution and no more than a total of five courses.

Withdrawal or Leave of Absence

A student who decides to leave the university must meet with their BXA advisor and complete a Withdrawal or Leave of Absence form. Withdrawal means leaving the university with no intention of returning. Leave of Absence means temporarily leaving the university with a stated intention to return. A withdrawal or leave of absence from the university at any time up to and including the last day of classes (excluding the final examination period), means that grades of W will be recorded for all classes for the semester. Financial responsibility for the semester is dependent upon the date of and the reasons for filing the form. Questions about financial responsibility should be directed to the HUB.

A leave of absence may be voluntary or involuntary. If the leave is voluntary, the student may return any time within four years following the beginning of the leave by filing an Application for Return from Leave of Absence form. If the leave is involuntary, that is, required for academic or disciplinary reasons, the conditions for return will be stated.

BXA Intercollege Program Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

52-190 BXA Seminar I: Building the Wunderkammer

Fall: 4.5 units
BXA Seminar I considers how knowledge is represented across different modes of mediawhat language, what symbols, what logic guides knowledge acquisition and expression in your varied disciplines? Students engage with theoretical and practical readings from across disciplines, with particular emphasis on interpretive theory. Weekly readings in aesthetic and critical theory introduce students to a particular vocabulary of analysis, practiced in class discussion and written responses. Students will conceive, research, produce and present a creative final project at the end of the course.

52-291 BXA Seminar II: Transferring Knowledge

Spring: 4.5 units
BXA Seminar II considers how interdisciplinary work can be produced, analyzed, justified andmost importantlycontextualized. By taking a deep dive into a single object or text, we'll explore how context situates the creator, the audience, and their relationship. At the end of the course, students will have a better understanding of how disciplinary methods establish context, and they'll be able to use this understanding to help guide their academic choices.

52-292 BXA Student Advisory Council

Intermittent: 3 units
This course will provide opportunities for students to promote and refine the mission of the BXA programs. Students will develop and practice leadership skills, including collaboration, communication, and project management. Students will be responsible for planning and running BXA student events, including info sessions, social hours, skills workshops, and alumni events. Students are encouraged to think about how to engage other interdisciplinary scholars and artists as well as how to present their own work and programs to the larger university community.

52-390 BXA Undergraduate Research Project

All Semesters
The BXA Undergraduate Research Project is for BXA students who want to work on a self-designed project with the one-to-one guidance of a faculty advisor. The project should be interdisciplinary in nature, and can be a scholarly and/or creative endeavor. The project may take the form of a written thesis, a compilation of creative works, an outreach project, etc. The project topic must be pre-approved by the faculty member who agrees to supervise the project and assign a letter grade for the course. Projects are to be completed in one semester, may be worth 3, 6, 9, or 12 units of academic credit, and cannot be taken concurrently with the BXA Capstone Project during the senior year. To register, students must submit an "Undergraduate Research Project Proposal Form" signed by both the student and the faculty advisor, along with a proposal, to their BXA academic advisor.

52-392 BXA Seminar III: Deconstructing Disciplines

Spring: 9 units
BXA Seminar III is in preparation for the BXA Capstone Project and/or other senior research projects (Dietrich/MCS/SCS thesis, or CFA senior studio work). The seminar will engage BXA juniors in a brief examination of the structures of disciplinary knowledge, interdisciplinary approaches, and the components of research, with production of original work as the primary class requirement. The course is designed with maximum flexibility for various schedule conflicts and attendance; check course syllabus for meeting times and options. Coursework includes short readings and self-assessment exercises, participation in seminar discussions, preparation of the Junior Portfolio and professional documents (CV), and the production of new research or creative works. These can take one of three forms: 1) a small proof of concept object 2) the initiation of one stage of larger research plans or 3) a complete Capstone proposal. Any of these may be the basis of the student's eventual Capstone or other senior work. The requirements for this semester also include a short 5 page literature review about the student's topic, inclusion of work during the BXA Kaleidoscope show (last week of April), and a class research presentation showcase held during the final exam period.

52-401 BXA Seminar IV: Capstone Project Research

Fall and Spring
The BXA Capstone gives BXA students the opportunity to demonstrate the extent of their interdisciplinary work over the course of their academic career. The Capstone should include elements that span the student's CFA and SCS concentrations (for BCSA students), CFA and engineering studies concentrations (for BESA students), CFA and DC concentrations (for BHA students), CFA and MCS concentrations (for BSA students), or CFA concentration and engineering major (for EA additional major students). The project can be either a scholarly or creative endeavor, and may take one of many possible forms (e.g., a written thesis, a compilation of creative work or works, an experiment and report, a computer program or animation, etc.). The BXA Capstone sequence covers both semesters of a student's senior year. In the fall, students are enrolled in 52-401 BXA Seminar IV: Capstone Project Research (9 units), which meets weekly to discuss strategies for managing research, planning the project, and larger theoretical issues related to interdisciplinary work. At the end of the fall course, students will have produced a Capstone Project proposal, an annotated bibliography, and multiple versions of their project pitch. In the spring, students enroll in 52-402 BXA Seminar: Capstone Project Production (9 units), which has no required classroom time. Instead, students spend the semester doing the research and foundational work necessary for the project, as well as meeting with their faculty and BXA advisors as they create their Capstone Project and prepare to present it at the annual Meeting of the Minds Undergraduate Research Symposium held each May. Students will only be enrolled for 18 units when they are unable to complete a two-semester sequence and need to gain special permission by the BXA Director/Academic Advisor. The BXA Capstone sequence is for students in their last two semesters before graduation.

52-402 BXA Seminar V: Capstone Project Production

Fall and Spring: 9 units
The BXA Capstone gives BXA students the opportunity to demonstrate the extent of their interdisciplinary work over the course of their academic career. The Capstone should include elements that span the student's CFA and SCS concentrations (for BCSA students), CFA and DC concentrations (for BHA students), CFA and MCS concentrations (for BSA students), or CFA concentration and engineering major (for EA additional major students). The project can be either a scholarly or creative endeavor, and may take one of many possible forms (e.g., a written thesis, a compilation of creative work or works, an experiment and report, a computer program or animation, etc.). The BXA Capstone sequence covers both semesters of a student's senior year. In the fall, students are enrolled in 52-401 BXA Seminar IV: Capstone Project Research (9 units), which meets weekly to discuss strategies for managing research, planning the project, and larger theoretical issues related to interdisciplinary work. At the end of the fall course, students will have produced a Capstone Project proposal, an annotated bibliography, and multiple versions of their project pitch. In the spring, students enroll in 52-402 BXA Seminar: Capstone Project Production (9 units), which has no required classroom time. Instead, students spend the semester doing the research and foundational work necessary for the project, as well as meeting with their faculty and BXA advisors as they create their Capstone Project and prepare to present it at the annual Meeting of the Minds Undergraduate Research Symposium held each May. The BXA Capstone sequence is for students in their last two semesters before graduation.

52-590 BXA Internship

All Semesters
An internship is a supervised professional work experience with clear links to a student's academic goals. BXA students may choose to complete a BXA Internship for elective credit with appropriate individuals or organizations within or outside of Carnegie Mellon University. Junior and senior BXA students in good academic standing are eligible to receive academic credit for one internship. Grading is pass/no pass only. Prior to enrolling in an internship, the student must have a "BXA Internship Agreement Form" signed by their site supervisor and approved by their BXA academic advisor.

Carnegie Mellon University-Wide Studies Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes *(*https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/*) each semester for course offerings and for any necessary pre-requisites or co-requisites.*

99-101 Core@CMU

Fall and Spring: 3 units
Core@CMU is an engaging, online learning experience where you'll develop your core competency skills in the Core4 domains - (1) Collaboration and amp; Teamwork, (2) Communication and amp; Presentation, (3) Information and amp; Data Literacy and (4) Intercultural and amp; Global Learning + Diversity, Equity and amp; Inclusion (IGL + DEI). Additionally, you'll discover evidence-based strategies to enhance your learning. This foundational course is an essential first step in your educational journey at CMU, setting you up for academic, personal, and professional success across any field of study. 99-101 is a remote course and coursework is designed to be completed asynchronously. Additionally, there are opportunities for synchronous engagement that will be offered in both in-person and remote modalities. Dates and times for these optional elements of the Core@CMU experience will be announced in the course Canvas site.

Course Website: http://www.cmu.edu/c-cm/

99-121 Peer Education Foundations

Fall and Summer: 3 units
The Peer Education Foundations course is a highly interactive and student-driven course; the material and activities focus on fostering and sharpening internally held knowledge, values, beliefs, creativity, and priorities. Students will reflect on and deepen their awareness of personal identities, skills, experiences, and goals using individual journaling activities as well as small and large group discussions. Students will analyze case studies to explore and discuss the role of identity in peer support. Hands-on practice and role play scenarios are interwoven into all lessons to deepen student's ability to and confidence in providing culturally responsive peer support. This course will also explore the application of the structural elements of peer support. Students will collaborate with peers to design programmatic systems including reporting conventions, leadership structure, outreach and marketing plans, and event planning. A critical lens is applied throughout the course as a way of centering students in the historical and cultural context in which peer education is being applied. Emphasis will be placed on student leadership within the context of Carnegie Mellon University. Academic support will be provided by campus and community partners. This course is part of the Certified Peer Educator (CPE) program offered through the National Association of Student Personnel Administrators (NASPA). Upon completion of this course, students will receive a CPE certification stating that they have been trained in the core skills that will make them a better leader, role model, activist, and team member. More information about the NASPA CPE Training is available on NASPAs website.

Course Website: https://www.naspa.org/project/certified-peer-educator-cpe-training (https://www.naspa.org/project/certified-peer-educator-cpe-training/)

99-129 DC Grand Challenge First-Year Seminar: Unreality: Immersive and Spatial Media

Intermittent: 9 units
Virtual news stories and game worlds are accessible by putting on cardboard goggles, theme parks are engineered to provide convincing multisensory experiences, and workforces are reliant on augmented views of factory floors. Immersive and spatial media constitute a suite of emerging technologies that offer the opportunity to expand arts, entertainment, science, design, commercial enterprises and countless other domains in ways that were previously limited to science fiction. The potential for augmented reality to disrupt our current technological ecosystem is tremendous. Many of these technologies are now 50 years old and just starting to enter the commercial realm. As immersive experiences and augmented realities become more integrated into our work and leisure, do we need to worry about the ways that unreality affect our experiences of reality, or our interactions with each other? How do we know that we can trust our senses to tell us what is real? How do we begin to grapple with the ethical, cultural, social, technological, and regulatory implications of this shift?

99-153 Mindful Living

Fall and Spring: 3 units
The goal of this course is to increase students internal resources for meeting stress through mindfulness-based meditation training. Each week, students will be trained in formal mindfulness meditation practices and asked to meditate at home with the help of brief guided meditation recordings. Students will also be given weekly informal mindfulness practice suggestions to help them translate the skills of formal meditation practice into daily life. Class meetings will give students the weekly opportunity for reflection, discussion, and questions based on their experience of formal and informal practice assignments.

99-190 Managing Stress, Restoring Harmony

Fall: 6 units
The course is designed to explore the subject of stress and how it can best be managed to achieve optimal health and wellbeing. Topics addressed will include: the environmental, mental and emotional components of stress, factors that affect the experience of stress, how stress contributes to illness, and an overview of various stress management techniques. Several lectures will be supported by Carnegie Mellon faculty and staff.

99-194 Intimate Relationships & Sexual Health

Spring: 6 units
This course will explore the expression of human relationships and sexuality. Emphasis will be placed on college health and the social, cultural and health factors that affect relational interactions. This course is designed to assist students with improved functioning in personal relationships, provide information to take care of their sexual health and help them acquire skills to make decisions now and in the future. Topic areas will include relationships, sexual behavior, sexual health and interpersonal skills. Academic support will be provided by campus and community partners.

99-250 Seminar for Peer Mentors

Fall and Spring: 1 unit
This course provides on-the-job training to students recently hired into Learning Support peer mentoring positions at the Student Academic Success Center. In this course, students will receive training and practice with the various skills required for their positions (e.g., active listening, creating sessions plans and reports, etc.). They will gain awareness of various campus units and resources (e.g., CaPS, Office of Disability Resources) and identify when and how to direct students to these resources. Additionally, students will explore the diversity of learners that they may encounter in their peer mentor positions, and they will practice inclusive mentoring strategies that help these students develop as self-directed learners. Students will have a chance to reflect on their own learning experiences and consider how their experiences might compare to those of other students. This seminar-style course will feature various instructional strategies, including guest speakers, small- and full-group discussion, case studies, and a variety of other active learning strategies. Students will complete an array of assignments, including position-specific documents, reflections, and peer observation/shadowing.

Course Website: http://www.cmu.edu/acadev/studentjobs/

99-262 ADDvocate: Anti-Discrimination Dialogue for Social Justice

Fall and Spring: 6 units
The aim of this multidisciplinary course is to establish a firm, education-based understanding of Diversity, Equity, and Inclusion topics in Pittsburgh, Qatar and Worldwide to enhance their classroom and university experience. Through a series of lectures by subject experts, this course aims to educate and raise consciousness of discrimination, racism and bias in the real world. This course will also highlight strategies to become an active bystander and advocate for fair treatment in all our communities.

99-264 Introduction to Life Design

Fall and Spring: 3 units
"What do you want to be when you grow up?" is a dysfunctional question that is asked by society to every child. The nature of this question implies individuals should have a single goal that they desire to reach - and that happiness/success will be achieved when this goal is reached. Instead, Introduction to Life Design asks individuals to explore what they want to grow into as life unfolds. Students in this course will identify what work and life mean to them, explore how their social identities influence how they engage with the world, ideate future possibilities, and learn how to explore those possibilities by prototyping experiences. This class is for juniors and seniors who want to learn how to create and navigate a life of meaning. Attendance is required at the Friday sessions because small group sharing is an integral part of the course pedagogy.

99-265 ADDvocate: Anti-Discrimination Dialogue

Fall and Spring: 9 units
The aim of this multidisciplinary course is to establish a firm, education-based understanding of Diversity, Equity, and Inclusion topics in Pittsburgh, Qatar and Worldwide to enhance students' classroom and university experience. This course consists of 9 units to provide students with a thorough overview of DEI topics. Through a series of lectures by subject experts, this course aims to educate and raise consciousness of discrimination, racism and bias in the real world. The course encourages students to critically examine their personal beliefs and opinions about race and discrimination. Students will also evaluate and analyze inequalities and systems of privilege that promote marginalization within key topics such as gender bias in research, discrimination in education, and discrimination practices in the healthcare system. Assessments include low-stakes assignments attached to weekly content and a final advocacy project. This course will also highlight strategies to become an active bystander and advocate for fair treatment in all our communities.

99-270 Summer Undergraduate Research Apprenticeship

Summer
This course consists of student participation in projects focused on undergraduate research or creative inquiry under the direction of a Carnegie Mellon faculty member. Tenure track, teaching track, research track, librarian track, and special faculty may serve as SURA mentors. The subject of the inquiry, the number of units, and the criteria for grading are to be determined by the student and the faculty mentor. This agreement should be formalized in a one-page apprenticeship verification form that includes documented approval from the faculty mentor with a copy to be submitted to the Undergraduate Research Office. The students are responsible for finding a faculty member who is willing and able to supervise them on campus over the summer. In addition to the research experience, course requirements include a series of workshop sessions over the course of the summer that will introduce students to the basics of research design. Students will also be expected to present and/or attend the campus-wide undergraduate research symposium, Meeting of the Minds, in May of the following year. Students may register for a maximum of nine units with work to be completed over an eight-week period during the summer all term.

99-352 IDeATe: Soft Fabrication Skills

Fall and Spring: 1 unit
PLEASE NOTE: The specific meeting dates for the A1 section of this micro course are Sep 14, Sep 21, Sep 28. Textiles are a ubiquitous part of our everyday tactile experience. This workshop series aims to introduce textile techniques to participants with diverse backgrounds across the CMU campus. The fabrication skills and concepts that will be covered in this course will be taught from an interdisciplinary approach to merge practices in arts and technology. Students will learn methods of working with fabric such as hand and machine sewing, felting and knitting, along with merging aspects of digital fabrication and physical computing using flexible materials. Through discussions and demos, participants will have the opportunity to explore new methods of fabrication to integrate into their own practice.

Course Website: https://courses.ideate.cmu.edu/99-352 (https://courses.ideate.cmu.edu/99-352/)

99-353 IDeATe: Design Essentials for Laser Cutting

Fall and Spring: 1 unit
PLEASE NOTE: The specific meeting dates for the A1 section of this micro course are Sep 21, Sep 28, Oct 5. The specific meeting dates for the A2 section of this micro course are Oct 27, Nov 3, Nov 10. This mini course is designed to get students ready to use a lasercutter. We will cover essential design considerations unique to lasercutting, material tolerances, available methods of assembly and finishing techniques, but the bulk of the class time is spent hands-on learning to design and create a lasercutter ready vector file. The primary software we use is Adobe Illustrator, with some time also spent in Photoshop for learning how to integrate raster images like photos and drawings into lasercut objects. Over the three classes, we will also discuss 2D, 2.5D and amp; 3D design basics, how to create tight joinery by understanding kerf, how to improve your photo engravings, and when switching software will save you a lot of time. Students who complete this course will be able to use the IDeATe facility's laser cutters on their own for future course work or personal projects.

99-355 IDeATe: Introduction to Arduino

Fall and Spring: 1 unit
PLEASE NOTE: The specific meeting dates for the A1 section of this micro course are Sep 20, Sept 27, and Oct 4. The specific meeting dates for the A2 section of this micro course are Oct 27, Nov 3, and Nov 10. This workshop aims to demystify the Arduino microcontroller through hands-on work in the lab creating simple machines with embodied behaviors. The Arduino is a versatile resource for physical projects for students in all disciplines. This course brings students over the beginner's threshold to a basic understanding of the use, terminology, and potential of the Arduino. The skills and concepts taught in this course are presented from an interdisciplinary approach which merges practices in arts and technology. The first portion will teach the essential skills for creating a simple sensor-driven physical computing system, and the second portion will reinforce those skills by making a simple interactive project. The course has no technical prerequisites, although uses a little bit of algebra-level math. Undergraduate students, graduate students, faculty and staff interested in learning new skills in an interdisciplinary environment are welcome!

Course Website: http://courses.ideate.cmu.edu/99-355 (http://courses.ideate.cmu.edu/99-355/)

99-357 IDeATe: Pragmatic Phototgraphy

Fall and Spring: 1 unit
PLEASE NOTE: The specific meeting dates for the A1 section of this micro course are Sep 29 and Oct 6. The specific meeting dates for the A2 section of this micro course are Oct 26 and Nov 2. Pragmatic Photography is a digital imaging course for the non-photographer. A tech-first approach provides a strong grounding in the core concepts and techniques of image-based media. This course will enable students to create photographs for project documentation. This class will not require special cameras or software; students will use commonly-available photo-editing software to create images using DSLRs, point and click cameras, or their cell phones. The course focuses on general principles that apply across different equipment and software.

99-361 IDeATe Portal

Spring: 9 units
Full descriptions of each section topic are available at https://ideate.cmu.edu/courses/portal-and-section-details.html. IDeATe Portal courses introduce students to key aspects of critical, creative, and technical practice and prepare them to engage in productive interdisciplinary Collaborative Studio coursework in IDeATe minor areas. Section A: Learning about Learning will provide an introduction to the science of learning. Students will learn about the different ways that people learn, the factors that influence learning, and how to apply this knowledge to their own learning and in designing learning experiences. Section B: Intelligent Environments is a hand-on, project-based course that introduces students to the issues and challenges of creating workable, affordable, and adaptable intelligent environments.

Course Website: https://ideate.cmu.edu/courses/portal-and-section-details.html

99-362 IDeATe: Intelligent Learning Spaces

Spring: 9 units
Intelligent Learning Spaces explores the interactions between human learning and the spaces in which learning occurs. In this project-based course, students discuss, analyze, define, and apply theory from education, architecture and the arts to their project work. Students investigate precedents and existing experiences to create their own learning manifestos and designs. Imagination, in-class participation, speculation, empathy and 360-degree awareness are key components of this class. Students work on scaffolded projects that build on their knowledge to showcase their intentions and creativity, reacting to a variety of contexts relevant to learning. Students have opportunities to develop creative inquiry skills and apply critical perspectives through project-based work that requires experimentations, hands-on learning, reflection, and documentation.

99-363 IDeATe: Spatial Storytelling

Spring: 6 units
Spatial Storytelling promotes the use of digital storytelling methods and methodologies across disciplinary topics. In this Spring mini, students are guided through the process from identifying a research problem, collecting data from diverse sources, learning specific geospatial mapping tools, and finally crafting narrative. They will work with spatial information (geospatial data) to build complex multimodal narratives around social issues. By the end of this course, students will know: what are spatial data, how to find and identify different types of spatial data, how to create a story based on data, and how to analyze data in geospatial software. Students will be able to develop constructive critique and data literacy skills to critically review peer work across disciplinary topics. Using competencies gained over the semester, students will create an online interactive narrative and present it to the broader community.

99-382 Technology, Humanity, and Social Justice: Environment

Fall: 3 units
As humans rely more and more on electronic devices to support their everyday activities, there are ever present warnings about the impacts such reliance has on human autonomy ranging from who owns and controls information networks, the inequitable impact of technology consumption on peoples and places, varying accessibility of technology around the globe, and the promises and limitations of technology in improving human health. By engaging in technology as a lens, this sequence of weekend micro-courses encourages students to examine technology as a system disproportionately impacting humanity by enabling and constraining human rights of groups of people around the globe. With a multi-disciplinary focus, the course invites researchers and practitioners from the University of Pittsburgh, Carnegie Mellon, and relevant fields more broadly. In Fall 2022, the focus will be on humanity's use of technology and the disparate impacts on and benefits to the environment and varying groups of people. This will include discussion around the material, environmental, and health costs of extracting materials necessary to technology development and production as well as the waste created by the consumption habits initiated by global reliance on technology. It will also include a discussion of technology's role in advancing sustainability. Added Note: The course will occur on Friday, Nov. 4th, Saturday, Nov. 5th, and Sunday, Nov. 6th. Engagement in the course should be synchronous; accommodations for those in significant time zone differences will be provided to allow enrollment and completion of all elements of the weekend. If a student is interested in the course but unable to engage in the course dates, please reach out to Korryn Mozisek (kmozisek@andrew.cmu.edu).

99-384 Technology, Humanity, and Social Justice: Health

Intermittent: 3 units
As humans rely more and more on electronic devices to support their everyday activities, there are ever present warnings about the impacts such reliance has on human autonomy ranging from who owns and controls information networks, the inequitable impact of technology consumption on peoples and places, varying accessibility of technology around the globe, and the promises and limitations of technology in improving human health. By engaging in technology as a lens, this sequence of weekend micro-courses encourages students to examine technology as a system disproportionately impacting humanity by enabling and constraining human rights of groups of people around the globe. With a multi-disciplinary focus, the course invites researchers and practitioners from the University of Pittsburgh, Carnegie Mellon, and relevant fields more broadly. In Fall 2023, the focus will be on the impact technology has on human health. This will include a discussion about technologys impact on human interactions, including mental health amid a pandemic and changing working conditions. It will also include a focus on the accessibility and disparities on health cares increased reliance on technology across the globe as well as the transition to digitizing health records and the dangers this creates in relation to privacy. Added Note: The course will occur on Friday, Oct. 27th, Saturday, Oct. 28th, and Sunday, Oct. 29th. Engagement in the course should be synchronous; accommodations for those in significant time zone differences will be provided to allow enrollment and completion of all elements of the weekend. If a student is interested in the course but unable to engage in the course dates, please reach out to Korryn Mozisek (kmozisek@andrew.cmu.edu).

99-385 Technology, Humanity, and Social Justice: Criminal Justice

Intermittent: 3 units
As humans rely more and more on electronic devices to support their everyday activities, there are ever present warnings about the impacts such reliance has on human autonomy ranging from who owns and controls information networks, the inequitable impact of technology consumption on peoples and places, varying accessibility of technology around the globe, and the promises and limitations of technology in improving human health. By engaging in technology as a lens, this sequence of weekend micro-courses encourages students to examine technology as a system disproportionately impacting humanity by enabling and constraining human rights of groups of people around the globe. With a multi-disciplinary focus, the course invites researchers and practitioners from the University of Pittsburgh, Carnegie Mellon, and relevant fields more broadly. In Spring 2024, the focus will be on the impact technology has on criminal justice. This will include a discussion about technology's impact on human safety, including the increasing use of machine learning, artificial intelligence, and other technology by various authorities of the criminal justice system. This will include discussions on the benefits and risks in the implementation and automation of such technology within criminal justice apparatuses. We will also consider how such implementation differs across global criminal justice systems, including how this technology is governed. Added Note: The course will occur on Friday, Mar. 22, Saturday, Mar. 23, and Sunday, Mar. 24. Engagement in the course should be synchronous; accommodations for those in significant time zone differences will be provided to allow enrollment and completion of all elements of the weekend. If a student is interested in the course but unable to engage in the course dates, please reach out to Korryn Mozisek (kmozisek@andrew.cmu.edu).

99-401 CMUQ ePortfolio/Capstone

All Semesters
Registration by special permission. This course is for CMUQ students who have declared a minor or are engaged in a certificate program. Students should contact the instructor(s) for permission to enroll. This course is a series of lessons/modules with guided activities to enable students to reflect on and synthesize their academic course of study. The activities may include independent research, reflective exercises, team projects, feedback from faculty, as well as external speakers and recent graduates who have expertise to share. Under the guidance of a faculty advisor, a student may undertake a project that is reflective in nature and synthesizes the student's academic coursework and educational experience throughout their minor or certificate program at CMUQ. The final project may be in various formats approved by the faculty advisor. The course will be offered in IPO or hybrid mode with all modules available through Canvas and/or Zoom. Each semester, the course will be facilitated by the students' course/project advisors. Additionally, students will regularly meet individually with the course instructor in person or through Zoom.

99-402 CMUQ ePortfolio/Capstone

All Semesters
Registration by special permission. This course is for CMUQ students who have declared a minor or are engaged in a certificate program. Students should contact the instructor(s) for permission to enroll. This course is a series of lessons/modules with guided activities to enable students to reflect on and synthesize their academic course of study. The activities may include independent research, reflective exercises, team projects, feedback from faculty, as well as external speakers and recent graduates who have expertise to share. Under the guidance of a faculty advisor, a student may undertake a project that is reflective in nature and synthesizes the student's academic coursework and educational experience throughout their minor or certificate program at CMUQ. The final project may be in various formats approved by the faculty advisor. The course will be offered in IPO or hybrid mode with all modules available through Canvas and/or Zoom. Each semester, the course will be facilitated by the students' course/project advisors. Additionally, students will regularly meet individually with the course instructor in person or through Zoom.

99-408 Get Career Ready: Unlocking Pathways to Success

All Semesters: 3 units
This course gives students the skills and knowledge they need to succeed in their chosen careers. By the end of the course, students will set meaningful career goals, create a plan to achieve them, develop their employability skills, and strategically position themselves for success in the competitive job market. Students will also gain insights from professional guest speakers who will share their experiences, perspectives, and industry-specific knowledge.

99-409 Summer Research

Summer: 1 unit
This course allows undergraduate students from all fields to participate in research (including artistic/creative inquiry) under the direction of a Carnegie Mellon faculty member. Tenure track, teaching track, research track, librarian track, and special faculty may serve as research supervisors. Students should have previously participated in summer research via the Summer Undergraduate Research Apprenticeship and/or the Summer Undergraduate Research Fellowship before enrolling in 99-409 (students who are unsure of whether 99-409 is appropriate for them should consult with the Undergraduate Research Office). Students will need to complete a supervisor agreement form to be eligible for participation in this tuition-free 1-unit course. Students are responsible for finding research supervisors. In addition to the summer research with the faculty member, students will be expected to write a brief (one- to two-page) research report about their summer work. This course is not eligible for CPT for international students; please contact the Office for International Education for more information regarding CPT.

99-520 Collaborative Research through Projects

Summer
This course has students engage in experiential learning via interdisciplinary projects around a variety of topics determined by each instructor. Students should review the lengthier descriptions for each section posted on the Office of the Vice Provost website under the Academic Resources tab to gain more knowledge of the projects and pre-requisites. https://docs.google.com/document/d/1JRPqsB15OBd-gWgrCuUXAqCnE7JApt4HmLehtNHyelk/edit?usp=sharing

Course Website: https://docs.google.com/document/d/1JRPqsB15OBd-gWgrCuUXAqCnE7JApt4HmLehtNHyelk/edit?usp=sharing (https://docs.google.com/document/d/1JRPqsB15OBd-gWgrCuUXAqCnE7JApt4HmLehtNHyelk/edit/?usp=sharing)

99-530 Senior Preparation Seminar

Fall and Spring: 6 units
This mini course provides graduating seniors a chance to reflect on their experiences as students at Carnegie Mellon; intellectually, socially and as leaders in this community. In addition to its reflective component, the course will also look at how to prepare for upcoming transitions into post college roles and responsibilities. The course explores intrapersonal, interpersonal, and external factors at play for recent graduates.

99-784 Technology, Humanity, and Social Justice: Health

Intermittent: 3 units
As humans rely more and more on electronic devices to support their everyday activities, there are ever present warnings about the impacts such reliance has on human autonomy ranging from who owns and controls information networks, the inequitable impact of technology consumption on peoples and places, varying accessibility of technology around the globe, and the promises and limitations of technology in improving human health. By engaging in technology as a lens, this sequence of weekend micro-courses encourages students to examine technology as a system disproportionately impacting humanity by enabling and constraining human rights of groups of people around the globe. With a multi-disciplinary focus, the course invites researchers and practitioners from the University of Pittsburgh, Carnegie Mellon, and relevant fields more broadly. In Fall 2023, the focus will be on the impact technology has on human health. This will include a discussion about technologys impact on human interactions, including mental health amid a pandemic and changing working conditions. It will also include a focus on the accessibility and disparities on health cares increased reliance on technology across the globe as well as the transition to digitizing health records and the dangers this creates in relation to privacy. Added Note: The course will occur on Friday, Oct. 27th, Saturday, Oct. 28th, and Sunday, Oct. 29th. Engagement in the course should be synchronous; accommodations for those in significant time zone differences will be provided to allow enrollment and completion of all elements of the weekend. If a student is interested in the course but unable to engage in the course dates, please reach out to Korryn Mozisek (kmozisek@andrew.cmu.edu).

Course Descriptions

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