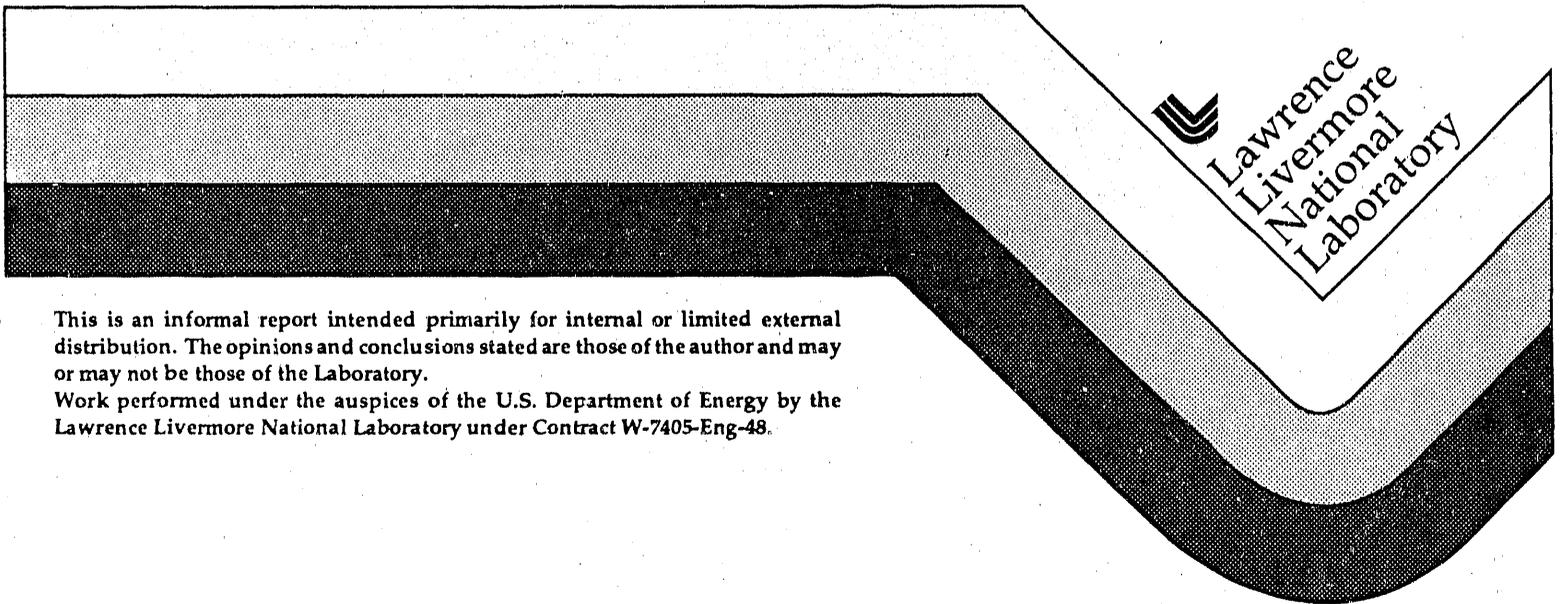


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**APTBLIBE:
Geometrical and Monte Carlo Sampling Routines
for the Cray Computer**

Arthur L. Edwards

April 1990



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APTBLIBE:
Geometrical and Monte Carlo Sampling
Subroutines for the Cray Computers

Arthur L. Edwards.

UCRL-ID--103432

1990 April 4.

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AVAILABILITY

The latest revisions of the BUILD library APTBLIBE and the user document APTDOC are in the LIB library APTSLIBE, and may be obtained by executing the following on a Cray computer:

```
xport read .245100:aptslibe!end / t v
lib aptslibe!x aptdoc aptblibe!end / t v
```

where the exclamation character "!" represents the linefeed key.

Older versions of the LIB library APTSLIBE may be obtained by executing:

```
xport list .245100:altslibh / t v
read .245100:altslibh:yymmdd
end
```

where yymmdd is a copy of APTSLIBE saved in year "yy", month "mm", and day "dd".

Library APTBLIBE is a BUILD library of Cray-compiled binary modules. Individual or sets of modules may be extracted and added to other BUILD libraries by using the BUILD utility routine, or all of the modules may be made available by specifying the APTBLIBE library in the CIVIC, CFT, and/or LOD directives.

You may view the user document APTDOC on a TMDS screen by executing:

```
trix ac!o!aptdoc!tvnnnn!p1 / t v
```

where nnnn is your TMDS number. The document may be searched as you would any other ASCII test file. To send a printed copy of the document to your box, execute:

```
allout hsp aptdoc box ann aptdoc / t v
```

where ann is your box number.

The FORTRAN source files for any of the binary modules in APTBLIBE may be extracted from LIB file APTSLIBE by executing:

```
lib aptslibe / t v
list alwith. apt s.
x filelist
end
```

where filelist is a list of the desired files. These may also be viewed with TRIX, and/or printed copies obtained with ALLOUT.

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ABSTRACT

APTBLIBE is a new BUILD library of about 151 Cray-compiled binary subroutines for numerical geometry and Monte Carlo sampling, of which 93 are described here (the rest will be described in a revision). It is designed especially to support 2-D and 3-D codes that generate and track beams or particles of energy or matter (APT = All-Particle-Tracking). The LIB library APTSLIBE contains the FORTRAN source files, and the user document APTDOC, much of which can be updated directly from the source files. This document describes APTBLIBE and its subroutines, how to use them, and the features designed to simplify the development of new codes, and improve the speed, efficiency, reliability and ease of maintenance of any codes which make use of it.

INTRODUCTION

Many large-scale computer programs at LLNL and elsewhere require code modules for generating and tracking beams or particles of energy or matter in various types of spatial meshes and coordinate systems, in 1-D, 2-D and 3-D geometries. Some of these modules require Monte Carlo sampling of random variables from a variety of probability distributions. These and other codes may also have to solve difficult geometric problems in generating and rezoning the mesh. As a result, a large number of subroutines, functions, and algorithms have been developed over the years for geometric and Monte Carlo sampling applications, greatly varying in style, structure, readability, accessibility, modularity, and efficiency. A single large code may have the same function duplicated many times, in many forms, in different code modules.

Thus, there is a clear need for one or more standard libraries of numerical geometry and Monte Carlo sampling subroutines, both for use in developing new codes, especially those for 3-D geometries, and for gradual replacement of coding in existing codes as they are upgraded. The goals in designing such libraries include improving speed, efficiency, accuracy, reliability, accessibility, readability, generality, flexibility, ease of maintenance, and ease of use.

The APTBLIBE library is designed to meet this immediate need, and to provide a basis for expansion to meet future needs. APTBLIBE already contains geometric and Monte Carlo sampling subroutines used by many Monte Carlo particle-tracking codes, in addition to a comprehensive set of basic subroutines for geometrical applications in 1-D, 2-D and 3-D geometries, in Cartesian, cylindrical and spherical coordinate systems. The development and inclusion in the library of additional higher-level subroutines is simplified by the hierarchical nature of the set of subroutines, and is being done as needed.

The subroutines in APTBLIBE, how to use them, and the methods used to accomplish the design goals will be described below.

WHAT IS IN APTBLIBE

APTBLIBE currently contains about 93 subroutines, ranging from basic low-level procedures to the higher-level geometric and Monte Carlo sampling methods needed for Monte Carlo tracking of beams and particles of energy and matter in 3-D geometries. These subroutines can be subdivided into five groups, as follows:

- The fundamental physical and chemical constants (2 subroutines).
- Mathematics and statistics (3 subroutines).
- Monte Carlo sampling (8+ subroutines).
- Precision and round-off error control (7 subroutines).
- Geometry (71+ subroutines).

A summary of the subroutines in each group follows. For a more detailed listing of subroutines by function, including the type of geometry and coordinate system, where applicable, see the appendix "SUBROUTINES BY FUNCTION" at the end of this document.

The latest self-consistent set of values of the fundamental constants of physics and chemistry are provided in two subroutines, aptconl (180 values in cm-g-sh-jerk-kev units), and aptconm (230 values in SI units). It is necessary to look at the source listing of each subroutine to find the index needed as an input argument to get the value of each constant.

The mathematics and statistics group consists of two subroutines for finding real roots of quadratic equations, aptqrts (scalar) and aptqrv (vector), and one subroutine for finding the mean and standard deviation of an array of values, aptmean. Each has unique features for control of round-off errors.

The Monte Carlo sampling group consists of 8+ subroutines for random sampling from probability distributions, including aptslid and aptsliv for 1-D uniform and linear distributions (with no sampling in negative regions), apttloc and aptqloc for 2-D uniform spatial distributions over triangles and quadrangles, respectively, aptscat for 3-D uniform directional distributions, aptscap for 3-D cosine**power directional distributions, aptscad for uniform directional distributions in a plane in 3-D space, aptxnup for frequencies from Plank or Wien distributions, and others.

The precision and round-off error control group consists of 7 subroutines, including aptfdad (scalar) and aptfdav (vector) for adjusting values of a variable near 0.0 and 1.0, aptvlic (2-D) and aptvlim (3-D) for imposing lower limits on the magnitudes of vector components, aptvtoc (2-D) and aptvtol (3-D) for applying any of several limit or truncation options to the magnitudes of spatial point coordinates or vector components, and aptrnds for rounding off floating point numbers to any specified relative or absolute precision. See the section titled "FUZZY GEOMETRY" below.

The geometry group consists of 74+ subroutines for a broad range of applications. These include conversion between various coordinate systems; doing basic vector and matrix operations; finding angle relationships between lines and between vectors; testing for special geometric relationships; doing the basic symmetry group operations of translation, rotation, reflection, and inversion, and combinations of these; linear and global scaling; finding distances; finding the initial vector direction and distance between two points in any coordinate system; moving a point a specified distance in a specified initial direction in any coordinate system; finding the alternate geometric descriptions of lines and planes; finding vectors perpendicular to lines in a major plane, or planes in 3-D space;

finding the vertex areas of a triangle; finding the vertex areas and shape (convex, boomerang or bowtie) of a quadrangle; finding the local coordinates (fractional distances between opposite sides) of points in quadrangles; finding the intersections between straight lines or linear tracks and various boundaries in 2-D and 3-D.

HOW TO USE APTBLIBE

APTBLIBE is a BUILD library currently containing about 93 Cray-compiled binary subroutines. The "availability" section at the beginning of this document tells how to get APTBLIBE, the source file LIB library APTSLIBE, and the user document APTDOC.

The appendix "SUBROUTINES BY FUNCTION" in this document contains a detailed summary of the subroutines in APTBLIBE by function, including the number of spatial dimensions and type of coordinate system, when applicable. This should allow a user to find the name of the subroutine with the required function, if it is in APTBLIBE.

The section of this document titled "SUBROUTINE DESCRIPTIONS IN ALPHABETIC ORDER" contains the initial comment block from each of the subroutines in APTBLIBE, extracted directly from the source files. Each comment block contains the calling statement and argument list, the dates of origination and last update, the location of the needed libraries and source file, the purpose and general description of the subroutine, lists of input and output arguments, a list of calls to other APTBLIBE subroutines, a history of significant changes that might affect the user, and a list of detailed definitions of all arguments. In most cases, this information should be sufficient to allow proper use of the subroutine. If not, the source file may be obtained from LIB library file APTSLIBE and read to obtain additional information, including definitions of all internal variables, comments describing each step of the procedure, and the coding itself. Each source file is intended to be completely self-documented.

For efficiency, 1-D and 2-D analogues of 3-D geometric algorithms have been placed in separate subroutines, to eliminate unnecessary subroutine arguments and complexity. All strictly 2-D subroutines, in which all points and vectors are confined to a major plane, have names ending in the letter "c". Subroutines are provided for rotating any non-major plane into a major plane. The rotation operator may be saved to do the inverse rotation later, after major-plane calculations are done.

Most of the subroutines in APTBLIBE are vectorized, and some algorithms are offered in two or more subroutines, depending on whether certain arguments are scalar values or array values, or on how certain geometric objects are defined. For example, a line may be represented by two points, or a point and a directional vector, or a plane may be represented by three points or a point and a normal vector. Subroutines are provided to interconvert between these representations.

All communication between APTBLIBE subroutines and each other, and with the calling program, is through argument lists. There are no shared cliches or common blocks. Input and output arrays in each argument list are usually members of a single table, with the same index and same array size. It is up to the user to allocate memory for these arrays, and put the input data into the required form. All local variables in APTBLIBE subroutines are declared in local labelled common blocks, named by prefixing the subroutine name with the letter "l". When local temporary arrays are needed, array processing is done in blocks of 64 or less, so no local array is sized any greater than 64.

Most subroutines indicate an input data error, failure to find a requested result, or the occurrence of a special or limiting case, by returning a scalar and/or array integer flag, or a physically impossible value of an output argument. Integer flags may have several possible values. The most often used flag, "nerr", is usually returned with a value of 1 when a specified array size is non-positive. The calling program should test for any of these cases that can possibly occur, and take appropriate action before errors propagate or a

crash occurs. Great care is taken to identify all special and extreme cases, and to indicate their occurrence to the calling program by use of the special result flags.

SUBROUTINE DESIGN

The subroutines in the APTBLIBE library were designed with the following goals: speed, efficiency, accuracy, reliability, accessibility, readability, generality, flexibility, ease of maintenance, and ease of use.

Calculational speed is obtained primarily by making maximum use of vectorization of do-loops, by eliminating unnecessary calculations by using separate subroutines for 2-D analogues of 3-D procedures, and by using input options to eliminate do-loops not needed for a particular application.

Efficiency is obtained by using a hierarchy of subroutines, beginning with a set of basic operations, followed by increasingly higher-level subroutines, making maximum use of calls to lower-level subroutines to avoid repetition of coding. This also helps to insure uniformity of method, increases reliability, simplifies maintenance, and simplifies the addition of higher-level user applications to the library.

Accuracy is obtained by thorough testing to eliminate coding errors, and by the careful use of the techniques of "fuzzy geometry", to eliminate or control the effects of numerical round-off errors. See the section of this document titled "FUZZY GEOMETRY TECHNIQUES".

Reliability is obtained by thorough testing, including all possible extreme, special, and degenerate cases, and all possible types of input errors, to ensure that the expected results are obtained in all cases, and that sufficient information is returned to the calling program to allow appropriate action to be taken in all cases, whenever possible. The test program for a particular subroutine is run whenever that subroutine, or any subroutine it is dependent on, is changed.

Accessibility is obtained by making all source files available in LIB library file APTSLIBE.

Readability is obtained by making each subroutine adhere to the same strict coding standard. The requirements include the inclusion of an initial block of comments containing certain required information (see the section of this document titled "SUBROUTINE DESCRIPTIONS IN ALPHABETIC ORDER") and liberal use of blank lines and comments. The coding standard also specifies the format of all FORTRAN statements, to ensure readability and uniformity in all subroutines. In general, the names of dummy arguments and local variables are chosen by a consistent set of rules in all subroutines, making it easier to remember their meanings.

Generality and flexibility are obtained by including all of the basic geometric and vector operations in separate subroutines, allowing a hierarchy of subroutines to be developed, ranging from low-level to high-level applications; by including separate subroutines for 1-D, 2-D and 3-D analogues of the same process, and for the same process carried out in different coordinate systems; and by including subroutines for conversion between different coordinate systems, and between different descriptions of the same geometric objects.

Ease of maintenance is obtained by a variety of methods, including use of a coding standard, use of a nomenclature standard, use of a hierarchical subroutine structure, and use of a number of computer tools for updating, compiling, loading, saving, and documenting, all of which are in place, and procedures for their use documented.

Ease of use is obtained by providing complete documentation, both here and in each source file, by allowing communication with the calling program only through the argument list, which eliminates any dependency on macros, cliches, or shared common blocks; by the use of a very basic set of FORTRAN statement types, minimizing or eliminating the need for changes to run on different computers; and by the general, flexible, and modular structure of the subroutines.

The average subroutine has 222 lines, of which 45 are blank, 75 are the initial comment block, 16 are other comments, 8 are dimension declarations for arguments, 13 are common block declarations for local variables, and the remaining 63 are other coding. Many of the latter have appended comments. (Note: appended comments are easily moved to a separate line by using `trix ac` with a simple `alter` file.)

FUZZY GEOMETRY TECHNIQUES

A unique feature of this library of subroutines is the inclusion and careful use of a number of techniques to control or eliminate the effects of round-off error due to the finite number of bits of precision available on the Crays and other computers.

These "fuzzy geometry" techniques make it possible to get correct and unambiguous answers to important geometric questions such as whether geometric objects are coincident, congruent, colinear, coplanar, parallel, perpendicular or tangent, within the uncertainty due to round-off error, and to avoid producing meaningless results that may later require special handling and testing to prevent major errors or program crashes.

Most subroutines have an input argument specifying a relative precision "tol", and allow certain intermediate and final results to be truncated to zero, if their absolute values are less than the estimated error in their calculation, based on "tol" and the actual numerical procedures used.

Other subroutines (aptdad, aptfdav, aptvtoc and aptvtol) provide a number of options to truncate or place limits on scalar values, spatial point coordinates, or vector components. Subroutine aptrnds may be used to round off any floating point number to a specified absolute or relative precision. These options may be tailored to the precision of the computer in use, and to the requirements of the particular application.

On the Crays, the value of "tol" should be approximately equal to $1.E-12^{**}(1/n)$, when the tested value x is to be used in the form $x^{**}n$. A larger value should be used (e.g., $1.E-11$), when the input arguments are likely to have been affected previously by round-off error.

Whenever an expression contains a denominator which can legitimately have a value of zero, a fuzz factor "fuz", equal to $1.E-99$, is added to the denominator, to avoid division by zero. The value $1.E-99$ might have to be changed on some computers. Whenever this technique results in an incorrect value of an output argument, either a separate warning flag is returned, or the description or the output argument in the subroutine comment block contains a warning, allowing the calling program to test for such results.

CRAY MEMORY REQUIREMENTS

The APTBLIBE library currently requires 72,000 words of Cray memory. The binary modules in APTBLIBE require an average of about 1000 words of Cray memory each, including about 250 words for the local common block. Since a call to one APTBLIBE subroutine may initiate a chain of calls to other lower-level APTBLIBE subroutines, as well as subroutines in other system libraries, the total memory requirement may be larger. Currently, the longest call chain is four.

SUBROUTINE DESCRIPTIONS IN ALPHABETIC ORDER

SUBROUTINE APTBANC

```
call aptbanc (au, av, bu, bv, cu, cv, np, tol,  
             bdu, bdv, du, dv, nerr)
```

Version: aptbanc Updated 1990 March 8 17:00.
aptbanc Originated 1990 March 8 17:00.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe!x aptblibe aptbanc!end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of np sets of input data, the bisector
bd = (bdu, bdv) of the angle "abc" formed by the points
a = (au, av), b = (bu, bv), and c = (cu, cv) in the uv plane,
and point d = (du, dv), the intercept of the bisector on
the line "ca". If points "a", "b" and "c" are colinear,
vector "bd" will be zero, and point "d" will be point "b".

Input: au, av, bu, bv, cu, cv, np, tol.

Output: bdu, bdv, du, dv, nerr.

Calls: aptvdic, aptvuac (sources in aptslibe,
binaries in aptblibe).

Glossary:

au, av	Input	The u and v coordinates of point "a". Size np.
bdu, bdv	Output	The u and v components of the vector "bd" which bisects angle "abc", and connects points "b" and "d".
bu, bv	Input	The u and v coordinates of point "b". Size np.
cu, cv	Input	The u and v coordinates of point "c". Size np.
du, dv	Output	The u and v coordinates of point "d" on line "ca". The intercept of bisector "bd" on line "ca". Size np.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays au, av, bu, bv, cu, cv, bdu, bdv, du, dv.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTBANG

```
call aptbang (ax, ay, az, bx, by, bz, cx, cy, cz,  
& np, tol, bdx, bdy, bdz, dx, dy, dz, nerr)
```

Version: aptbang Updated 1990 March 8 17:40.
aptbang Originated 1990 March 8 17:40.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibelx aptblibe aptbanglend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of np sets of input data, the bisector
bd = (bdx, bdy, bdz) of the angle "abc" formed by the points
a = (ax, ay, az), b = (bx, by, bz), and c = (cx, cy, cz),
and point d = (dx, dy, dz), the intercept of the bisector on
the line "ca". If points "a", "b" and "c" are colinear,
vector "bd" will be zero, and point "d" will be point "b".

Input: ax, ay, az, bx, by, bz, cx, cy, cz, np, tol.

Output: bdx, bdy, bdz, dx, dy, dz, nerr.

Calls: aptvdis, aptvuna (sources in aptslibe,
binaries in aptblibe).

Glossary:

ax,ay,az	Input	The x, y, z coordinates of point "a". Size np.
bdx,y,z	Output	The x, y, z components of the vector "bd" which bisects angle "abc", and connects points "b" and "d".
bx,by,bz	Input	The x, y, z coordinates of point "b". Size np.
cx,cy,cz	Input	The x, y, z coordinates of point "c". Size np.
dx,dy,dz	Output	The x, y, z coordinates of point "d" on line "ca". The intercept of bisector "bd" on line "ca". Size np.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays ax, ay, az, bx, by, bz, cx, cy, cz, bdx, bdy, bdz, dx, dy, dz.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTCINC

```
call aptcinc (ra, au, av, rb, bu, bv, np, tol,
             cu, cv, du, dv, nint, nerr)
```

Version: aptcinc Updated 1990 March 20 14:40.
 aptcinc Originated 1990 March 20 14:40.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe!x aptblibe aptcinclend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of np sets of input data, the points of
 intersection $c = (cu, cv)$ and $d = (du, dv)$ of the circle
 of radius ra at point $a = (au, av)$ and the circle of radius
 rb at point $b = (bu, bv)$, if an intersection occurs.
 Flag nint indicates the number of intersection points.
 Flag nerr indicates any input error.

Input: ra, au, av, rb, bu, bv, np, tol.

Output: cu, cv, du, dv, nint, nerr.

Calls: aptvdlc, aptvadc, aptvplc, aptvuac
 (sources in aptslibe, binaries in aptblibe).

Glossary:

au, av	Input	The u and v coordinates of point "a" at the center of the circle with radius ra, in the uv plane (2-D). Size np.
bu, bv	Input	The u and v coordinates of point "b" at the center of the circle with radius rb, in the uv plane (2-D). Size np.
cu, cv	Output	The u and v coordinates of point "c" at an intersection of the two circles centered at points "a" and "b", if an intersection occurs (nint = 1 or 2). Size np. Same as "d" if nint = 1. Meaningless, but set to "a" if nint = 0 or 3.
du, dv	Output	The u and v coordinates of point "d" at an intersection of the two circles centered at points "a" and "b", if an intersection occurs (nint = 1 or 2). Size np. Same as "c" if nint = 1. Meaningless, but set to "a" if nint = 0 or 3.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
nint	Output	Indicates the number of intersection points: 0 if no intersection occurs. Ignore points "c", "d". 1 if the circles are tangent at the single point "c" = "d". 2 if the circles overlap, intersecting at the two points "c" and "d". 3 if the circles are congruent. The intersection includes each circle. Ignore points "c", "d".
np	Input	Size of arrays.
ra	Input	The radius of the circle centered at point "a". Size np. The absolute value is used.
rb	Input	The radius of the circle centered at point "b". Size np. The absolute value is used.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTCONL

call aptconl (ind, np, pqcon, nerr)

Version: aptconl Updated 1990 March 2 15:30.
 aptconl Originated 1989 March 2 15:30.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Refs: 1. "The 1986 Adjustment of the Fundamental Physical Constants", Codata Bulletin Number 63, November 1986, Pergamon Press.

2. "Metric Practice Guide E 380-72e", 1973, American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa 19103.

3. File physcons in LIB library physlibe. Execute:

```
xport read .245100:physlibelend / t v
lib physlibelx physconslend / t v
allout hsp physcons / t v
trix aclophysconstvNNNNlpl / t v
```

Source: xport read .245100:aptslibe / 1 1
 lib aptslibelx aptblibe aptconlend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUIID library of Cray-compiled binaries.

Purpose: To provide the best available values of the fundamental physical constants and conversion factors of physics and chemistry, in cm-g-shake-keV units. See aptconm for SI units. For each of np values of ind, the constant with local index ind is returned in array pqcon. The local indices are tabulated below. For definitions of the constants, see the full listing of this subroutine, or reference 3 listed above. If any value of ind is not in the range from 1 to 180, the returned value of pqcon will be -1.e99.

1	pga	37	pgfrtoam	73	pgk	109	pgmsubmu	145	pgratde
2	pgab185	38	pgfrtog	74	pgketoam	110	pgmsubn	146	pgratdp
3	pgalpha	39	pgfrtojk	75	pgketojr	111	pgmsubp	147	pgratea
4	pgalpha1	40	pgfrtoke	76	pgketojk	112	pgmub	148	pgrated
5	pgamtohz	41	pgfrtorc	77	pgketorc	113	pgmube	149	pgratemu
6	pgamtojk	42	pgg	78	pgkevtog	114	pgmubf	150	pgratep
7	pgamtoke	43	pggamma	79	pglamce	115	pgmubw	151	pgratmue
8	pgamtorc	44	pggamp	80	pglamceb	116	pgmud	152	pgratne
9	pgamu	45	pggampb	81	pglamcn	117	pgmudb	153	pgratnp
10	pgamud	46	pggampp	82	pglamcnb	118	pgmudn	154	pgratpe
11	pgamue	47	pggamppb	83	pglamcp	119	pgmue	155	pgratpmu
12	pgamumu	48	pggolden	84	pglamcpb	120	pgmueb	156	pgrctoam
13	pgamun	49	pggsube	85	pglosch	121	pgmuen	157	pgrctofr
14	pgamup	50	pggsubmu	86	pgmagfq	122	pgmumu	158	pgrctog
15	pgamutog	51	pggsubn	87	pgmdev	123	pgmumub	159	pgrctojk
16	pgastar	52	pggtoamu	88	pgmdj	124	pgmumun	160	pgrctoke
17	pgasube	53	pggtofr	89	pgmeev	125	pgmun	161	pgrmole
18	pgasubmu	54	pggtojk	90	pgmej	126	pgmune	162	pgrydb
19	pgatm	55	pggtokev	91	pgmmrde	127	pgmunf	163	pgrydbc
20	pgatomx	56	pggtorc	92	pgmmrdp	128	pgmnt	164	pgrydbp
21	pgbohr	57	pgg	93	pgmmremu	129	pgmntb	165	pgrydbv
22	pgc	58	pghart	94	pgmmrep	130	pgmntn	166	pgsate
23	pgcsub1	59	pghartev	95	pgmmrmup	131	pgmunw	167	pgsatez
24	pgcsub2	60	pghbar	96	pgmmrne	132	pgmup	168	pgsb
25	pgcunit	61	pghbarc	97	pgmmrnp	133	pgmupb	169	pgsia
26	pgcuxun	62	pghbarok	98	pgmmuev	134	pgmupn	170	pgsid220
27	pgdrohm	63	pghlen	99	pgmmuj	135	pgmupp	171	pgsigw
28	pgc	64	pghmass	100	pgmnev	136	pgmuppb	172	pgsivolm
29	pgcbase	65	pghok	101	pgmnj	137	pgmuppn	173	pgtemp
30	pgec	66	pghtime	102	pgmolh	138	pgmuvac	174	pgthomx
31	pgcch	67	pgjfv	103	pgmolhc	139	pgnsuba	175	pgubb
32	pgcme	68	pgjkttoam	104	pgmoxun	140	pgomb185	176	pgv76bl
33	pgcemp	69	pgjkttofr	105	pgmpcv	141	pgqcirc	177	pgvmols
34	pgcspvac	70	pgjktog	106	pgmpj	142	pgqcirch	178	pgvmolz
35	pgcrao	71	pgjktoke	107	pgmsubd	143	pgqhc	179	pgwlen
36	pgcfar	72	pgjktorc	108	pgmsube	144	pgqhr	180	pi

Input: ind, np.
 Output: pgcon, nerr.
 Calls: none
 (sources in aptslibe, binaries in aptblibe).

Glossary:

ind Input Indices of constants to be stored in array pgcon.
 Size np.
 np Input Size of arrays ind, pgcon.
 pgcon Output Constants. Value pgcon(n) is constant with
 index ind(n).
 nerr Output Error flag. 1 if np is not positive.

Definitions:

SI UNIT AND CM-G-SHAKE UNIT CONVERSION FACTORS

Definitions and conversion of base units

Length or distance. 1 cm (centimeter) = 0.01 m (meter).
 Mass. 1 g (gram) = 0.001 kg (kilogram).
 Time. 1 sh (shake) = 1.0e-08 s (second).
 Electric current. 1 labA = 1 (jerk / cm)**0.5 = 1.0e+09 A (ampere).
 1 A = 1 C / s = (1.0e-07 J / m)**0.5.
 Temperature. 1 keV = 1.160445e+07 K (Kelvin).
 1 K = 1 / 273.16 of the thermodynamic temperature of
 the triple point of water.
 Note: 1988 NBS triple point of Gallium = 302.9169 K (1.7 ppm).

Definitions and conversion of derived units

Acceleration. 1 cm / sh**2 = 1.0e+14 m / s**2.
 Area. 1 cm**2 = 1.0e-04 m**2.
 Density. 1 g / cm**3 = 1.0e+03 kg / m**3.
 Electric capacitance. 1 labF = 1 sh**2 / cm = 1.0e-07 F (farad).
 1 F = 1 A s / V = 1.0e-07 s**2 / m.
 Electric inductance. 1 labH = 1 cm = 1.0e-09 H (henry).
 1 H = 1 V s / A = 1.0e+07 m.
 Electric resistance. 1 labohm = 1 cm / sh = 0.1 ohm.
 1 ohm = 1 V / A = 1.0e+07 m / s.
 Electric voltage. 1 labV = 1 (jerk cm / sh**2)**0.5 = 1.0e+08 V (volt).
 1 V = 1 W / A = (1.0e+07 J m / s**2)**0.5.
 Electrical charge. 1 labC = 1 (jerk sh**2 / cm)**0.5 = 10 C (coulomb).
 1 C = 1 A s = (1.0e-07 J s**2 / m)**0.5.
 Electrical conductance. 1 labS = 1 sh / cm = 10 S (siemen).
 1 S = 1 A / V = 1.0e-07 s / m.
 Electron volts. 1 keV (kiloelectron volts) = 1000 eV (electron volts).
 1 eV = 1.60217733e-19 J.
 Energy or work. 1 jerk = 1.0e+09 J (joule).
 1 J = 1 kg m**2 / s**2 = 1 N m (newton meter).
 Force. 1 g cm / sh**2 = 1 jerk / cm = 1.0e+07 N (newton).
 1 N = 1 Kg m / s**2 = 1 J / m.
 Magnetic flux. 1 labWb = 1 (jerk cm)**0.5 = 1 Wb (weber).
 1 Wb = 1 V s = (1.0e+07 J m)**0.5.
 Magnetic flux density. 1 labT = 1 (jerk / cm**3)**0.5 = 10,000 T (tesla).
 1 T = 1 Wb / m**2 = (1.0e+07 J / m**3)**0.5.

Power. 1 jerk / sh = 1.0e+17 W (watt).
1 W = 1 J / s = 1.0e-17 jerk / sh.

Pressure or energy density. 1 jerk / cm**3 = 1.0e15 Pa (pascal).
1 Pa = 1 N / m**2 = 1 J / m**3.

Specific heat. 1 jerk / (g keV) = 8.617385e+04 J / (kg K).

Thermal conductivity. 1 jerk / (sh cm keV) = 8.617385e+11 W / (m K).

Velocity. 1 cm / sh = 1.0e+06 m / s.

Volume. 1 cm**3 = 1.0e-06 m**3.

SUBROUTINE APTCONM

call aptconm (ind, np, pgon, nerr)

Version: aptconm Updated 1990 March 2 15:30.
 aptconm Originated 1989 March 2 15:30.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Refs: 1. "The 1986 Adjustment of the Fundamental Physical Constants", Codata Bulletin Number 63, November 1986, Pergamon Press.

2. "Metric Practice Guide E 380-72e", 1973, American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa 19103.

3. File physcons in LIB library physlibe. Execute:
 xport read .245100:physlibelnd / t v
 lib physlibelx physconslnd / t v
 allout hsp physcons / t v
 trix aclophysconstvNNNN|pl / t v

Source: xport read .245100:aptslibe / l 1
 lib aptslibelx aptblibe aptconmlnd / l 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To provide the best available values of the fundamental physical constants and conversion factors of physics and chemistry, in SI units. See aptconl for cm-g-shake-keV units. For each of np values of ind, the constant with local index ind is returned in array pgon. The local indices are tabulated below. For definitions of the constants, see the full listing of this subroutine, or reference 3 listed above. If any value of ind is not in the range from 1 to 217, the returned value of pgon will be -1.e99.

1	pga	45	pgevtoq	89	pgjtoq	133	pgmpv	177	pgratea
2	pgabi85	46	pgevtozm	90	pgjtozm	134	pgmpj	178	pgrated
3	pgad	47	pgfar	91	pgk	135	pgmsubd	179	pgratemu
4	pgalpha	48	pgg	92	pgkd	136	pgmsube	180	pgratemp
5	pgalpha1	49	pggamma	93	pgkgttoam	137	pgmsubmu	181	pgratmue
6	pgamtoev	50	pggamp	94	pgkgttoev	138	pgmsubn	182	pgratnue
7	pgamtoht	51	pggampb	95	pgkgttoht	139	pgmsubp	183	pgratnmp
8	pgamtohz	52	pggamppp	96	pgkgttohz	140	pgmub	184	pgratpue
9	pgamtoj	53	pggamppb	97	pgkgttoj	141	pgmube	185	pgratpmu
10	pgamtok	54	pggolden	98	pgkgtok	142	pgmubf	186	pgratold
11	pgamtokg	55	pggsube	99	pgkgtorm	143	pgmubk	187	pgratole
12	pgamtozm	56	pggsubmu	100	pgktoam	144	pgmubw	188	pgratoom
13	pgamu	57	pggsubn	101	pgktoev	145	pgmud	189	pgratovev
14	pgamud	58	pgh	102	pgktoht	146	pgmudb	190	pgratohd
15	pgamue	59	pghart	103	pgktohz	147	pgmudn	191	pgratohz
16	pgamumu	60	pghartev	104	pgktoj	148	pgmue	192	pgrattoj
17	pgamun	61	pghbar	105	pgktoq	149	pgmueb	193	pgratok
18	pgamup	62	pghbarc	106	pgktozm	150	pgmuen	194	pgratokq
19	pgastar	63	pghbarok	107	pglamce	151	pgmumu	195	pgrydb
20	pgasube	64	pghlen	108	pglamceb	152	pgmumub	196	pgrydbc
21	pgasubmu	65	pghmass	109	pglamcn	153	pgmumun	197	pgrydbe
22	pgatm	66	pghok	110	pglamcnb	154	pgmun	198	pgrydbev
23	pgatomx	67	pghtime	111	pglamcp	155	pgmune	199	pgsate
24	pgbohr	68	pghttoam	112	pglamcpb	156	pgmunf	200	pgsatez
25	pgc	69	pghttoev	113	pglosch	157	pgmunk	201	pgsb
26	pgcsub1	70	pghttohz	114	pgmagfq	158	pgmunt	202	pgsbd
27	pgcsub2	71	pghttoj	115	pgmdev	159	pgmuntb	203	pgsia
28	pgcsub2d	72	pghttok	116	pgmdj	160	pgmuntn	204	pgsid220
29	pgcunit	73	pghttokg	117	pgmeev	161	pgmunw	205	pgsigw
30	pgcuxun	74	pghttozm	118	pgmej	162	pgmup	206	pgsivolm
31	pgdrohm	75	pghyfsph	119	pgmmrde	163	pgmupb	207	pgtemp
32	pgc	76	pghztoam	120	pgmmrdp	164	pgmupn	208	pgtempd
33	pgcbase	77	pghztoev	121	pgmmremu	165	pgmupp	209	pgthomx
34	pgc	78	pghztoht	122	pgmmrep	166	pgmuppb	210	pgubb
35	pgc	79	pghztoj	123	pgmmrmup	167	pgmuppn	211	pgubbd
36	pgc	80	pghztok	124	pgmmrne	168	pgmuvac	212	pgv76bi
37	pgc	81	pghztokg	125	pgmmrnp	169	pgnsuba	213	pgvmolt
38	pgc	82	pghztozm	126	pgmmuev	170	pgombi85	214	pgvmoltz
39	pgc	83	pgjfv	127	pgmmuj	171	pgqclrc	215	pgwien
40	pgc	84	pgjtoamu	128	pgmnev	172	pgqclrch	216	pgwield
41	pgc	85	pgjtoev	129	pgmnj	173	pgqhc	217	pi
42	pgc	86	pgjtoht	130	pgmolh	174	pgqhr		
43	pgc	87	pgjtohz	131	pgmolhc	175	pgratde		
44	pgc	88	pgjtok	132	pgmoxun	176	pgratdp		

Input: ind, np.
 Output: pgcon, nerr.
 Calls: none
 (sources in aptslibe, binaries in aptblibe).

Glossary:

ind Input Indices of constants to be stored in array pgcon.
 Size np.
 np Input Size of arrays ind, pgcon.
 pgcon Output Constants. Value pgcon(n) is constant with
 index ind(n).
 nerr Output Error flag. 1 if np is not positive.

Definitions:

SI UNIT AND CM-G-SHAKE UNIT CONVERSION FACTORS

Definitions and conversion of base units

Length or distance. 1 cm (centimeter) = 0.01 m (meter).
 Mass. 1 g (gram) = 0.001 kg (kilogram).
 Time. 1 sh (shake) = 1.0e-08 s (second).
 Electric current. 1 labA = 1 (jerk / cm)**0.5 = 1.0e+09 A (ampere).
 1 A = 1 C / s = (1.0e-07 J / m)**0.5.
 Temperature. 1 keV = 1.160445e+07 K (Kelvin).
 1 K = 1 / 273.16 of the thermodynamic temperature of
 the triple point of water. Note: 1988 NBS triple point of Gallium = 302.9169 K (1.7 ppm).

Definitions and conversion of derived units

Acceleration. 1 cm / sh**2 = 1.0e+14 m / s**2.
 Area. 1 cm**2 = 1.0e-04 m**2.
 Density. 1 g / cm**3 = 1.0e+03 kg / m**3.
 Electric capacitance. 1 labF = 1 sh**2 / cm = 1.0e-07 F (farad).
 1 F = 1 A s / V = 1.0e-07 s**2 / m.
 Electric inductance. 1 labH = 1 cm = 1.0e-09 H (henry).
 1 H = 1 V s / A = 1.0e+07 m.
 Electric resistance. 1 labohm = 1 cm / sh = 0.1 ohm.
 1 ohm = 1 V / A = 1.0e+07 m / s.
 Electric voltage. 1 labV = 1 (jerk cm / sh**2)**0.5 = 1.0e+08 V (volt).
 1 V = 1 W / A = (1.0e+07 J m / s**2)**0.5.
 Electrical charge. 1 labC = 1 (jerk sh**2 / cm)**0.5 = 10 C (coulomb).
 1 C = 1 A s = (1.0e-07 J s**2 / m)**0.5.
 Electrical conductance. 1 labS = 1 sh / cm = 10 S (siemen).
 1 S = 1 A / V = 1.0e-07 s / m.
 Electron volts. 1 keV (kiloelectron volts) = 1000 eV (electron volts).
 1 eV = 1.60217733e-19 J.
 Energy or work. 1 jerk = 1.0e+09 J (joule).
 1 J = 1 kg m**2 / s**2 = 1 N m (newton meter).
 Force. 1 g cm / sh**2 = 1 jerk / cm = 1.0e+07 N (newton).
 1 N = 1 Kg m / s**2 = 1 J / m.
 Magnetic flux. 1 labWb = 1 (jerk cm)**0.5 = 1 Wb (weber).
 1 Wb = 1 V s = (1.0e+07 J m)**0.5.
 Magnetic flux density. 1 labT = 1 (jerk / cm**3)**0.5 = 10,000 T (tesla).
 1 T = 1 Wb / m**2 = (1.0e+07 J / m**3)**0.5.

Power. 1 jerk / sh = 1.0e+17 W (watt)
1 W = 1 J / s = 1.0e-17 jerk / sh.

Pressure or energy density. 1 jerk / cm**3 = 1.0e15 Pa (pascal).
1 Pa = 1 N / m**2 = 1 J / m**3.

Specific heat. 1 jerk / (g keV) = 8.617385e+04 J / (kg K).

Thermal conductivity. 1 jerk / (sh cm keV) = 8.617385e+11 W / (m K).

Velocity. 1 cm / sh = 1.0e+06 m / s.

Volume. 1 cm**3 = 1.0e-06 m**3.

SUBROUTINE APTCSYS

call aptcsys (n1, n2, iunit, u, v, w, np, tol, nerr)

Version: aptcsys Updated 1990 March 14 10:40.
aptcsys Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read ,245100:aptslibe / 1 1
lib aptslibelx aptblibe aptcsyslend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To transform the np points (u, v, w) from coordinate system n1 to coordinate system n2. Allowed coordinate systems are cartesian, cylindrical, spherical. Angles may be in degrees (iunit = 0) or radians (iunit = 1). Results will be truncated to zero if less than the estimated error in their calculation, based on tol. Disallowed input values of n1, n2, iunit, or np are indicated by a nonzero value of nerr.

Input: n1, n2, iunit, u, v, w, np, tol.

Output: u, v, w, nerr.

Glossary:

iunit	Input	Indicates unit to be used for angles: 0 if angles are in degrees. 1 if angles are in radians.
n1	Input	Indicates initial coordinate system type: 0 for cartesian coordinates. u = x, v = y, w = z. 1 for cylindrical coordinates. u = radius from z axis, v = angle in xy plane, counterclockwise from x axis, w = z. 2 for spherical coordinates. u = radius from origin, v = angle in xy plane, counterclockwise from x axis, w = angle from z axis.
n2	Input	Indicates final coordinate system. See n1.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 2 if either n1 or n2 is not 0, 1, or 2. 3 if n1 = n2. 4 if iunit is not 0 or 1.
np	Input	Number of points (u, v, w).
tol	Input	Numerical tolerance limit. Any angle with a sine or cosine (absolute value) less than tol will be adjusted to make its sine or cosine = 0.
u,v,w	In/Out	The coordinates of a point. Size np. See n1, n2. Will be truncated to zero, if less than the estimated error in their calculation, based on tol.

SUBROUTINE APTCSYV

call aptcsyv (n1, n2, iunit, u, v, w, au, av, aw, np,
tol, nerr)

Version: aptcsyv Updated 1989 December 1 13:10.
aptcsyv Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptcsyv|end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To transform the np points (u, v, w) and
the associated bound vectors a = (au, av, aw) from
coordinate system n1 to coordinate system n2. Allowed
coordinate systems are cartesian, cylindrical, spherical.
Note: if (u, v, w) is at the origin, then au and av are
independent of the coordinate system, and aw changes sign
between the spherical coordinate system and the other two.
Angles may be in degrees (iunit = 0) or radians (iunit = 1).
Results will be truncated to zero if less than the estimated
error in their calculation, based on tol. Disallowed input
values of n1, n2, iunit, or np are indicated by a nonzero
value of nerr.

Input: n1, n2, iunit, u, v, w, au, av, aw, np, tol.

Output: u, v, w, au, av, aw, nerr.

Glossary:

au,av,aw	In/Out	The u, v, w components of a bound vector at (u, v, w). Size np.
iunit	Input	Indicates unit to be used for angles: 0 if angles are in degrees. 1 if angles are in radians.
n1	Input	Indicates initial coordinate system type: 0 for cartesian coordinates. u = x, v = y, w = z. 1 for cylindrical coordinates. u = radius from z axis, v = angle in xy plane, counterclockwise from x axis, w = z. 2 for spherical coordinates. u = radius from origin, v = angle in xy plane, counterclockwise from x axis, w = angle from z axis.
n2	Input	Indicates final coordinate system. See n1.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 2 if either n1 or n2 is not 0, 1, or 2. 3 if n1 = n2. 4 if iunit is not 0 or 1.
np	Input	Number of points (u, v, w), and number of bound vectors (au, av, aw).
tol	Input	Numerical tolerance limit. Any angle with a sine or cosine (absolute value) less than tol will be adjusted to make its sine or cosine = 0. Any spatial coordinate or vector component with a final value less than the estimated error in its calculation, based on tol, will be truncated to zero.
u,v,w	In/Out	The coordinates of a point. Size np. See n1, n2. Will be truncated to zero, if less than the estimated error in their calculation, base on tol.

SUBROUTINE APTDIST

```
call aptdist (nsys, iunit, au, av, aw, bu, bv, bw,  
& np, tol, cu, cv, cw, dab, nerr)
```

Version: aptdist Updated 1990 March 14 16:00.
aptdist Originated 1989 November 27 16:50.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptdistlend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, the distance dab, and initial unit direction vector $c = (cu, cv, cw)$, from the point $a = (au, av, aw)$ to the point $b = (bu, bv, bw)$.
Option nsys specifies the coordinate system:
0 for Cartesian, 1 for cylindrical, 2 for spherical.
Option iunit indicates the units for angles: 0 for degrees, 1 for radians.
Any component of vector "c" less than the estimated error in its calculation, based on tol, will be truncated to zero.
Vector "c" will be zero, if point "a" is coincident with point "b", based on tol.
Flag nerr indicates any input error.

History: 1990 March 14. Changed tol to 0.0 in call to unit vector subroutine. Allows small magnitudes.

Input: nsys, iunit, au, av, aw, bu, bv, bw, np, tol.

Output: cu, cv, cw, dab, nerr.

Calls: aptcsys, aptcsyv, aptvdis, aptvuna
(sources in aptslibe, binaries in aptblibe).

Glossary:

au,av,aw	Input	The u, v, w coordinates of point "a". Size np.
bu,bv,bw	Input	The u, v, w coordinates of point "b". Size np.
cu,cv,cw	Output	The u, v, w components of vector "c". Size np. May be truncated to zero, if less than the estimated numerical error in their calculation based on tol.
dab	Output	The distance from point "a" to point "b". Size np.
iunit	Input	Indicates unit to be used for angles: 0 if angles are in degrees. 1 if angles are in radians.
nsys	Input	Indicates coordinate system type: 0 for cartesian coordinates. $u = x, v = y, w = z$. 1 for cylindrical coordinates. $u =$ radius from z axis, $v =$ angle in xy plane, counterclockwise from x axis, $w = z$. 2 for spherical coordinates. $u =$ radius from origin, $v =$ angle in xy plane, counterclockwise from x axis, $w =$ angle from z axis.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 2 if nsys is not 1, 2, or 3. 3 if iunit is not 0 or 1.
np	Input	Size of arrays.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTFDAD

call aptfdad (fd, noptfd, tol, nlim, nerr)

Version: aptfdad Updated 1990 January 18 16:40.
aptfdad Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe!x aptblibe aptfdad!end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To adjust the value of fd, relative to the limits 0 and 1,
based on the option noptfd and the numerical tolerance limit
tol. Values of fd initially in the range from -tol to 1 + tol
may be adjusted to the range from tol to 1 - tol. Values of fd
outside the range from 0 to 1 may be adjusted to that range.
The flag nlim indicates if and how fd was adjusted.
Flag nerr indicates any error in noptfd.

Input: fd, noptfd, tol.

Output: fd, nlim, nerr.

Glossary:

fd	Input	Fractional distance.
fd	Output	Fractional distance, with range limited if noptfd is 1 or 2.
nerr	Output	Indicates an input error, if not 0. 1 if noptfd is not between 0 and 2.
nlim	Output	0 if no limit imposed on fd, 1 if the limit of noptfd = 1 is imposed, 2 if the limit of noptfd = 2 is imposed.
noptfd	Input	Option to limit range of fd: 0 for no limit; 1 to increase fd to tol, if in the range from -tol to tol, and decrease fd to 1.0 - tol, if in the range from 1.0 - tol to 1.0 + tol; and 2 to impose the limits for noptfd = 1, and then limit fd to the range from 0.0 to 1.0.
tol	Input	Numerical tolerance limit. Needed if noptfd = 1 or 2. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTFDAV

call aptfdav (fd, np, noptfd, tol, nlim, nerr)

Version: aptfdav Updated 1990 January 18 14:20.
aptfdav Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptfdav|end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To adjust the np values of fd, relative to the limits 0 and 1, based on the option noptfd and the numerical tolerance limit tol. Values of fd initially in the range from -tol to 1 + tol may be adjusted to the range from tol to 1 - tol. Values of fd outside the range from 0 to 1 may be adjusted to that range. The flag nlim indicates if and how fd was adjusted. Flag nerr indicates any error in noptfd.

Input: fd, np, noptfd, tol.

Output: fd, nlim, nerr.

Glossary:

fd(n)	Input	Fractional distance. Size np.
fd(n)	Output	Fractional distance, with range limited if noptfd is 1 or 2. Size np.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 2 if noptfd is not between 0 and 2.
nlim(n)	Output	0 if no limit imposed on fd, 1 if the limit of noptfd = 1 is imposed, 2 if the limit of noptfd = 2 is imposed. Size np.
noptfd	Input	Option to limit range of fd: 0 for no limit; 1 to increase fd to tol, if in the range from -tol to tol, and decrease fd to 1.0 - tol, if in the range from 1.0 - tol to 1.0 + tol; and 2 to impose the limits for noptfd = 1, and then limit fd to the range from 0.0 to 1.0.
np	Input	Size of arrays fd, nlim.
tol	Input	Numerical tolerance limit. Needed if noptfd = 1 or 2. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTFDQC

```
call aptfdqc (au, av, bu, bv, cu, cv, du, dv, pu, pv, np, tol,
             fdk, fdl, ngood, nerr)
```

Version: aptfdqc Updated 1990 January 26 16:20.
 aptfdqc Originated 1990 January 26 16:20.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibelx aptblibe aptfdqclend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, the fractional distances fdk and fdl of the point $p = (pu, pv)$, between the opposite edges "da" and "bc", and "ab" and "cd", respectively, of the 2-D quadrilateral in the uv plane with vertices $a = (au, av)$, $b = (bu, bv)$, $c = (cu, cv)$, and $d = (du, dv)$. Flag $nerr$ indicates any input error.

Input: au, av, bu, bv, cu, cv, du, dv, pu, pv, np, tol.

Output: fdk, fdl, ngood, nerr.

Calls: aptqrv (source in aptslibe, binary in aptblibe).

Glossary:

au, av	Input	The u and v coordinates of point "a" in the uv plane. Size np.
bu, bv	Input	The u and v coordinates of point "b" in the uv plane. Size np.
cu, cv	Input	The u and v coordinates of point "c" in the uv plane. Size np.
du, dv	Input	The u and v coordinates of point "d" in the uv plane. Size np.
fdk	Output	Fractional distance of point "p" from the line segment "da" to the line segment "bc". Size np. Values between $-tol$ and tol will be adjusted to tol . Values between $1.0 - tol$ and $1.0 + tol$ will be adjusted to $1.0 - tol$. See ngood.
fdl	Output	Fractional distance of point "p" from the line segment "ab" to the line segment "cd". Size np. Values between $-tol$ and tol will be adjusted to tol . Values between $1.0 - tol$ and $1.0 + tol$ will be adjusted to $1.0 - tol$. See ngood.
ngood	Output	Indicates range of fractional distances fdk and fdl : 0 if either fdk or fdl is outside the range from $-tol$ to $1.0 + tol$. Also if both are. 1 if fdk and fdl are both between $-tol$ and $1.0 + tol$. This can be true even when point "p" is outside a boomeranged or bowtied quadrangle. 2 if fdk and fdl are both between $-tol$ and $1.0 + tol$, and two possible solutions exist. This can happen when the quadrangle is a boomerang or bowtie. Only one of the solutions is returned.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays pu, pv, au, av, bu, bv, cu, cv, du, dv, fdk, fdl.
pu, pv	Input	The u and v coordinates of point "p" in the uv plane. Size np.
tol	Input	Numerical tolerance limit. On Cray computers, recommend $1.e-5$ to $1.e-11$.

SUBROUTINE APTINVC

call aptinvc (au, av, pu, pv, np, tol, nerr)

Version: aptinvc Updated 1990 March 13 11:30.
aptinvc Originated 1990 January 4 13:20.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptinvc|end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To invert the np points or vectors $p = (pu, pv)$ through the point $a = (au, av)$, all in the uv plane. If "p" are unbound vectors, point $a = (au, av)$ should be at the origin. The new components of "p" will be truncated to zero if less than the estimated error in their calculation, based on tol. Flag nerr indicates any input error.

Input: itype, au, av, pu, pv, np, tol.

Output: pu, pv, nerr.

Glossary:

au, av	Input	The u and v components of the inversion point "a".
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Number of 2-D points or vectors (pu, pv).
pu, pv	In/Out	The u and v coordinates of a 2-D point, or the u and v components of a 2-D vector. Size np. Truncated to zero if less than the estimated error in their calculation. See tol.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTINVP

call aptinvp (ax, ay, az, px, py, pz, np, tol, rinv)

Version: aptinvp Updated 1990 March 13 11:30.
aptinvp Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptinvp:end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the matrix operator rinv for inversion through the origin, and to do an equivalent inversion through the point a = (ax, ay, az), of the np points or vectors p = (px, py, pz). If "p" are unbound vectors, point "a" must be at the origin. The new components of "p" will be truncated to zero if less than the estimated error in their calculation, based on tol.

Input: itype, ax, ay, az, px, py, pz, np, tol.

Output: px, py, pz, rinv.

Glossary:

ax,ay,az	Input	The x, y, z coordinates of the inversion point "a".
np	Input	Number of points or vectors (px, py, pz). May be 0.
px,py,pz	In/Out	The x, y, z coordinates of a point, or the x, y, z components of a vector. Size np. Truncated to zero if less than the estimated error in their calculation. See tol.
rinv	Output	Array rinv(3,3). Inversion operator. Diagonal elements are -1. Off-diagonal elements are 0.
tol	Input	Numerical tolerance limit. Used to test and adjust point components. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTLNIC

```
call aptlnic (au, av, bu, bv, rc, cu, cv, np, tol,
             du, dv, eu, ev, nint, nerr)
```

Version: aptlnic Updated 1990 March 21 13:40.
 aptlnic Originated 1990 March 21 13:40.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe|x aptblibe aptlnic|end / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of np sets of input data, any intersection points $d = (du, dv)$ and $e = (eu, ev)$ of the line through points $a = (au, av)$ and $b = (bu, bv)$, and the circle centered at point $c = (cu, cv)$ with radius rc , all in the uv plane. Flag nint indicates the number or type of intersection points. Flag nerr indicates any input error.

Input: au, av, bu, bv, rc, cu, cv, np, tol.

Output: du, dv, eu, ev, nint, nerr.

Calls: aptqrtv, aptvadc, aptvdic, aptvdoc
 (sources in aptslibe, binaries in aptblibe).

Glossary:

au, av	Input	The u and v coordinates of point "a" on the line "ab" in the uv plane. Size np.
bu, bv	Input	The u and v coordinates of point "b" on the line "ab" in the uv plane. Size np.
cu, cv	Input	The u and v coordinates of point "c" at the center of the circle in the uv plane with radius rc. Size np.
du, dv	Output	The u and v coordinates of point "d" at an intersection of the line "ab" and the circle of radius rc centered at point "c", if an intersection occurs (nint = 1 or nint = 2). Meaningless if nint = -1 or 0. Size np.
eu, ev	Output	The u and v coordinates of point "e" at an intersection of the line "ab" and the circle or radius rc centered at point "c", if an intersection occurs (nint = 2). Meaningless if nint = -1, 0 or 1. Size np.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
nint	Output	Indicates the type and number of intersection points: -1 if points "a" and "b" coincide, based on tol. Points "d" and "e" are meaningless. 0 if no intersection occurs. Points "d" and "e" are meaningless. 1 if the line and circle are tangent at the single point "d". Point "e" is meaningless. 2 if the line and circle intersect at the two distinct points "d" and "e".
np	Input	Size of arrays.
rc	Input	The radius of the circle in the uv plane, centered at point "c". The absolute value is used.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTINLC

call aptinlc (au, av, bu, bv, cu, cv, du, dv, np, tol,
 & dmin, fracab, fraccd, eu, ev, ipar, nerr)

Version: aptinlc Updated 1990 January 18 16:40.
 aptinlc Originated 1990 January 11 11:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100;aptslibe / 1 1
 lib aptslibe|x aptblibe aptinlc|end / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of np sets of input data, the intersection $e = (eu, ev)$, if any, between the straight line between points $a = (au, av)$ and $b = (bu, bv)$, and the straight line between points $c = (cu, cv)$, and $d = (du, dv)$, all in the uv plane, where u, v and w are orthogonal directions. The fractional distance fracab of point "e" along line "ab", and the fractional distance fraccd of point "e" along line "cd" are also returned. If the lines are parallel, ipar = 1 will be returned, and the distance dmin between the lines will be returned. If dmin is smaller than the estimated error in its calculation, it will be truncated to zero. If a line segment is too short, ipar = 2, 3 or 4 will be returned. Flag nerr will be 1 if np is not positive.

Input: au, av, bu, bv, cu, cv, du, dv, np, tol.

Output: dmin, fracab, fraccd, eu, ev, ipar, nerr.

Calls: aptvdc, aptaxc (sources in aptslibe,
 binaries in aptblibe).

Glossary:

au, av	Input	The u and v coordinates of the first point on line segment "ab" in the uv plane. Size np.
bu, bv	Input	The u and v coordinates of the second point on line segment "ab" in the uv plane. Size np.
cu, cv	Input	The u and v coordinates of the first point on line segment "cd" in the uv plane. Size np.
dmin	Output	Distance from line "ab" to line "cd", when they are parallel (ipar = 1). Truncated to zero if less than the estimated error in its calculation. See tol. Size np.
du, dv	Input	The u and v coordinates of the second point on line segment "cd" in the uv plane. Size np.
eu, ev	Output	The u and v coordinates of the intersection of lines "ab" and "cd". Size np.
fracab	Output	Fractional distance of "e" along line "ab". Size np. Meaningless if ipar = 2 or 4.
fraccd	Output	Fractional distance of "e" along line "cd". Size np. Meaningless if ipar = 3 or 4.
ipar	Output	0 if lines are not parallel. 1 if they are. Size np. 2 if line segment "ab" is too short. 3 if line segment "cd" is too short. 4 if "ab" and "cd" are both too short.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
tol	Input	Numerical tolerance limit. On Cray Computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTLNLN

```
call aptlnln (ax, ay, az, bx, by, bz, cx, cy, cz,
             dx, dy, dz, np, tol, dpmin, fracab, fraccd,
             ex, ey, ez, fx, fy, fz, itrunc, ipar, nerr)
```

Version: aptlnln Updated 1990 March 14 16:00.
 aptlnln Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read ,245100;aptslibe / 1 1
 lib aptslibelx aptblibe aptlnlnend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries#.

Purpose: To find, for each of np sets of input data, the minimum distance dpmin between the line through the points a = (ax, ay, az) and b = (bx, by, bz), and the line through the points c = (cx, cy, cz) and d = (dx, dy, dz), and the point e = (ex, ey, ez) on line "ab", and the point f = (fx, fy, fz) on line "cd", at which the minimum distance dpmin occurs. If dpmin is smaller than the estimated error in its calculation, it will be truncated to zero, and itrunc = 1 will be returned.
 The fractional distance fracab of point "e" along line "ab", and the fractional distance fraccd of point "f" along line "cd", are also returned.
 If the lines are parallel, ipar = 1 will be returned.
 If a line segment is too short, ipar = 2, 3 or 4 will be returned.

History: 1990 March 14. Changed tol to 0.0 in call to unit vector subroutine. Allows small magnitudes.

Input: ax, ay, az, bx, by, bz, cx, cy, cz, dx, dy, dz, np, tol.

Output: dpmin, fracab, fraccd, ex, ey, ez, fx, fy, fz,
 itrunc, ipar, nerr.

Calls: aptvdis, aptvdot, aptvuna (sources in aptslibe,
 binaries in aptblibe).

Glossary:

- ax,ay,az Input The first point on line segment "ab". Size np.
- bx,by,bz Input The second point on line segment "ab". Size np.
- cx,cy,cz Input The first point on line segment "cd". Size np.
- dpmin Output Minimum distance from line "ab" to line "cd".
 Distance from e = (ex, ey, ez) to f = (fx, fy, fz).
 Truncated to zero if less than the estimated error
 in its calculation. See tol. Size np.
- dx,dy,dz Input The second point on line segment "cd". Size np.
- ex,ey,ez Output The x, y, z coordinates of the point on line "ab"
 nearest line "cd". Size np.
- fx,fy,fz Output The x, y, z coordinates of the point on line "cd"
 nearest line "ab". Size np.
- fracab Output Fractional distance of "e" along line "ab". Size np.
 Meaningless if ipar = 2 or 4.
- fraccd Output Fractional distance of "f" along line "cd". Size np.
 Meaningless if ipar = 3 or 4.
- ipar Output 0 if lines are not parallel. 1 if they are, and
 points "e" and "f" can be moved arbitrarily by
 equal distances along the lines. Size np.
 2 if line segment "ab" is too short.
 3 if line segment "cd" is too short.
 4 if "ab" and "cd" are both too short.
- itrunc Output 0 if dpmin not truncated to zero, based on tol.
 1 if dpmin is truncated to zero, based on tol.
 Size np.

nerr	Output	Indicates an input error, if not 0, 1 if np is not positive.
np	Input	size of arrays,
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTLNPL

```

call aptlnpl (px, py, pz, sx, sy, sz, ax, ay, az,
&           vnx, vny, vnz, np, tol, dpmn, dint, fracps,
&           qx, qy, qz, ipar, nerr)

```

Version: aptlnpl Updated 1990 March 15 13:40.
 aptlnpl Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe|x aptblibe aptlnplend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUIID library of Cray-compiled binaries.

Purpose: To find, for each of np sets of input data, the point of intersection of the line through points $p = (px, py, pz)$ and $s = (sx, sy, sz)$, with the plane through the point $a = (ax, ay, az)$ with normal vector $vn = (vnx, vny, vnz)$. The point of intersection will be defined by its distance dint from point "p", its fractional distance fracps along the line from "p" to "s", and its coordinates $q = (qx, qy, qz)$. The perpendicular distance dpmn from the plane to point "p" is also returned.

If point "p" coincides with point "s", based on tol, the result will be the same as if line "ps" is parallel to the plane. If vector "vn" is too short, based on tol, the result will be the same as if line "ps" lies in the plane. If line "ps" is parallel to the plane, ipar will be 1. If, in addition, dpmn is not zero, dint, fracps, and the coordinates of "q" will be very large. If the line is parallel to the plane and dpmn is zero, then the line is in the plane, and dint and fracps will be zero, and the coordinates of "q" will be (px, py, pz).

Flag nerr indicates any input error.

History: 1990 March 14. Changed tol to 0.0 in call to unit vector subroutine. Allows small magnitudes.
 1990 March 15. Changed results when vector "vn" is too short. Now gives same results as if line "ps" is in the plane.

Input: px, py, pz, sx, sy, sz, ax, ay, az, vnx, vny, vnz, np, tol.

Output: dint, dpmn, fracps, qx, qy, qz, ipar, nerr.

Calls: aptvadd, aptvdis, aptvdot, aptvuna, aptvunb
 (sources in aptslibe, binaries in aptblibe).

Glossary:

ax,ay,az	Input	The x, y, z coordinates of point "a" in the plane. Size np.
dint	Output	The distance of the point of intersection "q" from point "p". Positive if in the same direction as that from "p" to "s". Size np. Meaningless if ipar is not zero.
dpmn	Output	The perpendicular distance to point "p" from the plane. Positive if point "p" is in the same direction from the plane as the normal vector "vn". If less than the estimated error in its calculation, dpmn will be truncated to zero. Size np. Meaningless if ipar = 2, 3, or 4.
fracps	Output	Fractional distance of point "q" along the line segment from point "p" to point "s". Size np. May be negative or greater than 1. Meaningless if ipar is not zero.
ipar	Output	0 if the line is not parallel to the plane. Size np. 1 if it is. See dpmn, dint, fracps, qx, qy, qz. 2 if line "ps" is too short, based on tol. 3 if vector "vn" is too short, based on tol. 4 if "ps" and "vn" are both too short, based on tol.

nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays.
px,py,pz	Input	The x, y, z coordinates of point "p" on the line. Must differ from "s", based on tol. Size np.
qx,qy,qz	Output	The x, y, z coordinates of the point of intersection of the line through "p" and "s" with the plane through point "a" with normal vector "vn". Meaningless if ipar is not zero.
sx,sy,sz	Input	The x, y, z coordinates of point "s" on the line. Must differ from "p", based on tol. Size np.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.
vnx,y,z	Input	The x, y, z components of vector "vn" normal to the plane. Magnitude must exceed tol. Size np.

SUBROUTINE APTMAXW

call aptmaxw (tgas, np, ertest, beta, gamma, nerr)

Version: aptmaxw Updated 1990 January 31 16:30.
aptmaxw Originated 1990 January 31 16:30.

Authors: Eugene H. Canfield, LLNL, L-298, Telephone (415) 422-4125.
Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe/x aptblibe aptmaxw/ 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of np specified temperatures tgas, the relativistic velocity functions beta and gamma, by sampling from a relativistic Maxwellian distribution of particles with a rest mass energy of ertest (same units as tgas). Flag nerr indicates any input error.

Input: tgas, np, ertest.

Output: beta, gamma, nerr.

Glossary:

beta	Output	Ratio of particle velocity to the speed of light: $\beta = v / c$ ($c = 2.99792458 \times 10^8$ m / s). Range is from 0.0 to 1. Size = np.
ertest	Input	The rest mass of the particles (same units as tgas).
gamma	Output	Ratio of relativistic mass to particle rest mass: $\gamma = \sqrt{1.0 - \beta^2}$. Range is from 0.0 to infinity. Size np.
nerr	Output	Indicates an input error, if not zero. 1 if np is not positive.
np	Input	Size of arrays tgas, beta, gamma.
tgas	Input	Average particle temperature (same units as ertest). Size np.

SUBROUTINE APTMEAN

call aptmean (x, np, tol, xmean, xdev, nerr)

Version: aptmean Updated 1990 January 31 14:10.
aptmean Originated 1990 January 31 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100;aptslibe / 1 1
lib aptslibe|x aptblibe aptmean|end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for the np values of x, the mean value xmean and
the standard deviation xdev of x from xmean.
Flag nerr indicates any input error.

Input: x, np, tol.

Output: xmean, xdev, nerr.

Glossary:

nerr	Output	If not 0, indicates an input error. 1 if np is not positive.
np	Input	Size of array x.
tol	Input	Truncation error limit. On Cray computers, recommend 1.e-11.
x	Input	A scalar value. Size np.
xdev	Output	Standard deviation of x from xmean. $\text{sqrt}(\text{mean}(x**2) - (\text{mean}(x))**2)$.
xmean	Output	Mean value of x. $\text{Sum}(x) / \text{np}$.

SUBROUTINE APTMOPV

call aptmopv (smat, inv, ax, ay, az, px, py, pz, np, tol, nerr)

Version: aptmopv Updated 1990 March 14 19:30.
 aptmopv Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe|x aptblibe aptmopv|end / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To transform the np points or vectors $p = (px, py, pz)$ by subtracting $a = (ax, ay, az)$, then operating on the result with the 3 x 3 matrix operator smat (inv = 0) or its transpose (inv = 1), then adding $a = (ax, ay, az)$. Components of "p" smaller than the estimated error in their calculation, based on tol, will be truncated to zero. If np is not positive, nerr = 1 will be returned. If inv is not 0 or 1, nerr = 2 will be returned.

(1) if smat is a rotation operator (unitary, orthogonal, the transpose = the inverse, and the cosine of the rotation angle is $(\text{trace} - 1) / 2$), the rotation is around an axis through the point $a = (ax, ay, az)$. Option inv = 0 rotates the 3 row vectors of smat to be parallel to the major axes, or rotates the major axes to be parallel to the 3 column vectors of smat. Option inv = 1 rotates the 3 column vectors of smat to be parallel to the major axes, or rotates the major axes to be parallel to the 3 row vectors of smat.

(2) if smat is a reflection operator (unitary, symmetric, its own inverse, and the trace = 1) the reflection is in a plane through the point $a = (ax, ay, az)$; inv has no effect. If the values $p = (px, py, pz)$ are unbound vectors, then $a = (ax, ay, az)$ must be $(0., 0., 0.)$. The sequential application of two reflections is a rotation and a possible translation.

(3) if smat is an inversion operator (diagonals = -1, other elements = 0), the inversion is through the point $a = (ax, ay, az)$.

History: 1990 March 13. Deleted truncation of components based on total magnitude of vector.

Input: smat, inv, ax, ay, az, px, py, pz, np, tol.

Output: px, py, pz, nerr.

Glossary:

ax,ay,az	Input	The x, y, z coordinates of an invariant point.
inv	Input	0 to operate with the matrix smat, 1 to operate with its transpose.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 2 if inv is not 0 or 1.
np	Input	Size of arrays px, py, pz. Must be positive.
px,py,pz	In/Out	The x, y, z coordinates of a point, or the x, y, z components of a vector. Size np. Components smaller than the estimated error in their calculation, based on tol, will be truncated to zero.
smat	Input	Array smat(3,3). A matrix operator.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTMOVE

```
call aptmove (nsys, iunit, au, av, aw, bu, bv, bw, dpmove,
&            np, tol, cu, cv, cw, du, dv, dw, nerr)
```

Version: aptmove Updated 1990 January 18 14:20.
 aptmove Originated 1989 November 22 17:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe|x aptblibe aptmove!end / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, the new point $c = (cu, cv, cw)$ and unit direction vector $d = (du, dv, dw)$, resulting from moving from the point $a = (au, av, aw)$ in the direction of the unit vector $b = (bu, bv, bw)$ for a distance dpmove.
 Option nsys specifies the coordinate system:
 0 for Cartesian, 1 for cylindrical, 2 for spherical.
 Option iunit indicates the units for angles: 0 for degrees, 1 for radians.
 Any component of point "c" or vector "d" less than the estimated error in its calculation, based on tol, will be truncated to zero.
 Flag nerr indicates any input error.

Input: nsys, iunit, au, av, aw, bu, bv, bw, dpmove, np, tol.

Output: cu, cv, cw, du, dv, dw, nerr.

Calls: aptcsyv, aptvadd (sources in aptslibe, binaries in aptblibe).

Glossary:

au,av,aw	Input	The u, v, w coordinates of point "a". Size np.
bu,bv,bw	Input	The u, v, w components of unit vector "b". Size np.
cu,cv,cw	Output	The u, v, w coordinates of point "c". Size np. May be truncated to zero, if less than the estimated numerical error in their calculation based on tol.
dpmove	Input	The distance from point "a" to point "c". Size np. (Assuming vector "b" is a unit vector.)
du,dv,dw	Output	The u, v, w components of unit vector "d". Size np. May be truncated to zero, if less than the estimated numerical error in their calculation based on tol.
iunit	Input	Indicates unit to be used for angles: 0 if angles are in degrees. 1 if angles are in radians.
nsys	Input	Indicates coordinate system type: 0 for cartesian coordinates. u = x, v = y, w = z. 1 for cylindrical coordinates. u = radius from z axis, v = angle in xy plane, counterclockwise from x axis, w = z. 2 for spherical coordinates. u = radius from origin, v = angle in xy plane, counterclockwise from x axis, w = angle from z axis.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 2 if nsys is not 1, 2, or 3. 3 if iunit is not 0 or 1.
np	Input	Size of arrays.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTMOV5

```

call aptmov5 (rhos, cths, sths, cphs, sphs,
&            usrh, uth, usph, dpmove, np, tol,
&            rho, cth, sth, cph, sph, urh, uth, uph, nerr)

```

Version: aptmov5 Updated 1990 March 14 16:00.
aptmov5 Originated 1989 December 4 17:00.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptmov5lend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, the new point p = (rho, cth, sth, cph, sph) and unit direction vector u = (urh, uth, uph), resulting from moving from the point ps = (rhos, cths, sths, cphs, sphs) in the direction of the unit vector us = (usrh, uth, usph) for a distance dpmove, in spherical coordinates.
Any component of point "p" or vector "u" less than the estimated error in its calculation, based on tol, will be truncated to zero. If tol = 0, no truncation tests are done. Flag nerr indicates any input error.

History: 1990 March 14. Changed tol to 0.0 in call to unit vector subroutine. Allows small magnitudes.

Input: rhos, cths, sths, cphs, sphs, usrh, uth, usph, dpmove, np, tol.

Output: rho, cth, sth, cph, sph, urh, uth, uph, nerr.

Calls: aptvuna (source in aptslibe, binary in aptblibe).

Glossary:

cph	Output	The cosine of the final value of phi (angle from the z axis). May be truncated to zero, if less than the estimated numerical error in their calculation based on tol. Size np.
cphs	Input	The cosine of the initial value of phi. See uph. Size np.
cth	Output	The cosine of the final value of theta (angle in the xy plane counterclockwise from x axis). May be truncated to zero, if less than the estimated numerical error in their calculation based on tol. Size np.
cths	Input	The cosine of the initial value of theta. See cth. Size np.
dpmove	Input	The distance from point "ps" to point "p". Size np. (Assuming vector "us" is a unit vector.)
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays.
rho	Output	The spherical radial component of final point "p". May be truncated to zero, if less than the estimated numerical error in their calculation based on tol. Size np.
rhos	Input	The spherical radial component of initial point "ps". Size np.
sphs	Input	The sine of the initial value of phi. See cph. Size np.
sph	Output	The sine of the final value of phi. See cph. May be truncated to zero, if less than the estimated numerical error in their calculation based on tol. Size np.

sths	Input	The sine of the initial value of theta. See cth. Size np.
sth	Output	The sine of the final value of theta. See cth. May be truncated to zero, if less than the estimated numerical error in their calculation based on tol. Size np.
tol	Input	Numerical tolerance limit. If zero, no tests done. On Cray computers, recommend 1.e-5 to 1.e-11.
uph	Output	The phi component of final unit direction vector "u". May be truncated to zero, if less than the estimated numerical error in their calculation based on tol. See cph. Size np.
urh	Output	The rho component of final unit direction vector "u". May be truncated to zero, if less than the estimated numerical error in their calculation based on tol. Size np.
usph	Input	The phi component of initial unit direction vector "us". See cph. Size np.
usrh	Input	The rho component of initial unit direction vector "us". Size np.
usth	Input	The theta component of initial unit direction vector "us". See cth. Size np.
uth	Output	The theta component of final unit direction vector "u". May be truncated to zero, if less than the estimated numerical error in their calculation based on tol. See cth. Size np.

SUBROUTINE APTMPRD

call aptmprd (nrows, smat1, smat2, tol, smat, nerr)

Version: aptmprd Updated 1989 December 29 11:40.
aptmprd Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptmprdiend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the matrix product smat of the two square matrices
smat1 and smat2. Each must be sized nrows by nrows.
Considered as operators, smat is equivalent to the sequential
application of smat2, then smat1. Components of smat within
tol of 0, 1, or -1 will be adjusted to those values.
If nrows is not positive, nerr = 1 will be returned.

Input: smat1, smat2.

Output: smat, nerr.

Glossary:

nerr	Output	Indicates an input error, if not 0. 1 if nrows is non-positive.
nrows	Input	Number of rows = number of columns in smat1, smat2, and smat.
smat	Output	A square matrix, with size smat(nrows,nrows). matrix product of smat1, smat2.
smat1	Input	A square matrix, with size smat1(nrows,nrows).
smat2	Input	A square matrix, with size smat2(nrows,nrows).
tol	Input	Numerical tolerance limit. Used to test and adjust matrix elements. If the row and column vectors of smat1 and smat2 are unit vectors, then On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTMVCY

```

call aptmvcy (kth, psz, psr, cths, sths, usz, usr, ust,
             dpmove, np, tol,
             pz, pr, cth, sth, uz, ur, ut, nerr)

```

Version: aptmvcy Updated 1990 March 14 16:00.
 aptmvcy Originated 1989 December 4 11:00.

Author: Arthur L. Edwards, LNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe|x aptblibe aptmvcylend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, the new point $p = (pz, pr, cth, sth)$ and unit direction vector $u = (uz, ur, ut)$, resulting from moving from the point $ps = (psz, psr, cths, sths)$ in the direction of the unit vector $us = (usz, usr, ust)$ for a distance dpmove, in cylindrical coordinates.
 If $kth = 0$, all $cths = 1.0$, all $sths = 0.0$, and cth and sth will not be calculated, and none need be dimensioned. Any component of point "p" or vector "u" less than the estimated error in its calculation, based on tol, will be truncated to zero. If $tol = 0$, no truncation tests are done. Flag nerr indicates any input error.

History: 1990 March 14. Changed tol to 0.0 in call to unit vector subroutine. Allows small magnitudes.

Input: kth, psz, psr, cths, sths, usz, usr, ust, dpmove, np, tol.

Output: pz, pr, cth, sth, uz, ur, ut, nerr.

Calls: aptvuna (source in aptslibe, binary in aptblibe).

Glossary:

		Size np.
cth	Output	The cosine of the final value of theta (angle in the xy plane counterclockwise from x axis). May be truncated to zero, if less than the estimated numerical error in their calculation based on tol. Size np, if $kth = 1$. Otherwise, not calculated.
cths	Input	The cosine of the initial value of theta. See cth. Size np, if $kth = 1$. Otherwise, scalar 1.0.
dpmove	Input	The distance from point "ps" to point "p". Size np. (Assuming vector "us" is a unit vector.)
kth	Input	Indicates size of arrays cth, cths, sth, sths: 0 if array size is 1, with $cths = 1.0$, $sths = 0.0$, and cth and sth are not to be calculated. 1 if array size is np, input values of $cths$ and $sths$ will be used, and cth and sth will be calculated.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 2 if kth is not 0 or 1.
np	Input	Size of arrays.
pr, pz	Output	The r and z components of final point "p". Size np. May be truncated to zero, if less than the estimated numerical error in their calculation based on tol.
psr, psz	Input	The r and z coordinates of initial point "ps". Size np.
sths	Input	The sine of the initial value of theta. See cth. Size np, if $kth = 1$. Otherwise, scalar 0.0.
sth	Output	The sine of the final value of theta. See cth. May be truncated to zero, if less than the estimated numerical error in their calculation based on tol. Size np, if $kth = 1$. Otherwise, not calculated.

tol	Input	Numerical tolerance limit. If zero, no tests done. On Cray computers, recommend 1.e-5 to 1.e-11.
ur	Output	The r component of final unit direction vector "u". May be truncated to zero, if less than the estimated numerical error in their calculation based on tol. Size np.
usr	Input	The r component of initial unit direction vector "us". Size np.
ust	Input	The theta component of initial unit direction vector "us". See cth. Size np.
usz	Input	The z component of initial unit direction vector "us".
ut	Output	The theta component of final unit direction vector "u". May be truncated to zero, if less than the estimated numerical error in their calculation based on tol. See cth. Size np.
uz	Output	The z component of final unit direction vector "u". Size np.

SUBROUTINE APTPLPL

```

call aptplpl (ax, ay, az, bx, by, bz, cx, cy, cz,
&            dx, dy, dz, np, tol, ex, ey, ez, fx, fy, fz,
&            ux, uy, uz, ipar, dpmin, itrunc, nerr)

```

Version: aptplpl Updated 1990 March 15 15:10.
 aptplpl Originated 1989 November 9 10:00.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe|x aptblibe aptplplend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of a set of input data, the line of intersection of the plane through point $a = (ax, ay, az)$ with normal vector $b = (bx, by, bz)$, and the plane through point $c = (cx, cy, cz)$ with normal vector $d = (dx, dy, dz)$, if any. Otherwise, if the planes are parallel, to find the distance between them. For nonparallel planes, the points $e = (ex, ey, ez)$ and $f = (fx, fy, fz)$ will be the points on the line of intersection nearest points "a" and "c", respectively, unit vector $u = (ux, uy, uz)$ will be the direction of the line of intersection, and ipar will be zero.

If the planes are parallel, based on tol, ipar will be 1, and dpmin will be the the distance between the planes. If the planes are coincident, dpmin will be zero, itrunc will be 1, and unit vector "u" will be in the direction of the line "ac".

Flag nerr indicates any input error, such as np not positive. Flag ipar will be 2, 3, or 4 if vector "b" or "d", or both, are too short, based on tol. If so, "e", "f" and "u" will be meaningless.

Method: The line of intersection "ef" lies in both planes, therefore is perpendicular to both normal vectors, thus parallel to $b \times d$. The line "ae" is perpendicular to line "ef" and "b", thus parallel to $b \times (b \times d)$. The line "cf" is perpendicular to line "ef" and "d", thus parallel to $d \times (b \times d)$. The vector path "ac" equals the vector path "aefc". Taking components parallel to "ae", "ef", and "cf" provides equations for the unknown distances "ae", "ef", and "cf". If the planes are parallel, $b \times d$ is zero, and dpmin is the component of "ac" in the direction of the normal vector "b".

Note: Subroutine aptvpln may be used to find the vector normal to a plane for which at least 3 points are known.

History: 1990 March 14. Changed tol to 0.0 in call to unit vector subroutine. Allows small magnitudes.
 1990 March 15. Changed points "e" and "f" to "a" and "b", resp. when either vector "b" or "d" is too small. No effect when input data is good.

Input: ax, ay, az, bx, by, bz, cx, cy, cz, dx, dy, dz, np, tol.

Output: ex, ey, ez, fx, fy, fz, ux, uy, uz, ipar, dpmin, itrunc, nerr.

Calls: aptvadd, aptvdis, aptvdot, aptvuna, aptvunb, aptvxun
 (sources in aptslibe, binaries in aptblibe).

Glossary:

ax,ay,az	Input	A point in plane "a". Size np.
bx,by,bz	Input	A vector normal to plane "a". Size np. If too short, based on tol, ipar = 2 or 4.
cx,cy,cz	Input	A point in plane "c". Size np.
dx,dy,dz	Input	A vector normal to plane "c". Size np. If too short, based on tol, ipar = 3 or 4.
ex,ey,ez	Output	The x, y, z coordinates of the point on the line of intersection of planes "a" and "c" nearest point "a". Meaningless, but point "a", if ipar is not 0.

fx, fy, fz	Output	The x, y, z coordinates of the point on the line of intersection of planes "a" and "c" nearest point "c". Meaningless, but point "c", if ipar is not 0.
dpmin	Output	The distance between planes "a" and "c", if ipar = 1. Otherwise, zero. Size np.
ipar	Output	Indicates relative orientation of planes "a" and "c": 0 if the planes intersect. 1 if the planes are parallel, based on tol. 2 if vector "b" is too short, based on tol. 3 if vector "d" is too short, based on tol. 4 if vectors "b" and "d" are both too short. Orientation is indeterminate if ipar = 2, 3 or 4. Size np.
itrn	Output	If 1, indicates planes are parallel and coincident. Size np.
nerr	Output	Indicates #n input error, if not 0. 1 if np is not positive.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.
ux, uy, uz	Output	The x, y, z components of the unit vector parallel to the line of intersection of planes "a" and "c", if ipar = 0. Meaningless, but parallel to the line "ac" if ipar is not zero. Size np.

SUBROUTINE APTPLSP

```
call aptplsp (rsph, px, py, pz, ax, ay, az, bx, by, bz, np,
4          tol, dpmn, rcir, cx, cy, cz, itrn, nerr)
```

Version: aptplsp Updated 1990 March 16 14:10.
 aptplsp Originated 1990 March 16 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe|x aptslibe aptplsplend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptslibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of np sets of input data, the minimum distance dpmn to the point p = (px, py, pz), from the plane through the point a = (ax, ay, az) with normal vector b = (bx, by, bz), and the coordinates c = (cx, cy, cz) of the point in the plane nearest point "p". In addition, to find the radius rcir of any circle of intersection of the plane with the sphere centered at point "p" with radius rsph. Flag itrn indicates truncation of dpmn to zero (1) or too small a magnitude of vector "b" (2). Flag nerr indicates any input error.

Input: rsph, px, py, pz, ax, ay, az, bx, by, bz, np, tol.

Output: dpmn, rcir, cx, cy, cz, itrn, nerr.

Call: aptptpl (source in aptslibe, binary in aptslibe).

Glossary:

ax, ay, az	Input	The x, y, z coordinates of point "a" in the plane. Size np.
bx, by, bz	Input	The x, y, z components of vector "b" normal to the plane. Magnitude must exceed tol. Size np.
cx, cy, cz	Output	The x, y, z coordinates of the point in the plane nearest point "p". Size np. The center of any circle of intersection. Returned as point "p" if normal vector "b" is too short, based on tol (itrn = 2).
dpmn	Output	The perpendicular distance to point "p" from the plane through point "a" with normal vector "b". Positive if point "p" is in the same direction from the plane as the normal vector "b". Truncated to zero if less than the estimated error in its calculation, based on tol (itrn = 1). Returned as zero if normal vector "b" is too short, based on tol (itrn = 2).
itrn	Output	Indicates a special result for one data set: 0 if dpmn is not zero, and no input errors occur. 1 if the value of dpmn is truncated to zero, when less than the estimated error in its calculation, based on tol. 2 if normal vector "b" is too short, based on tol. The orientation of the plane is unknown, and dpmn and point "c" cannot be calculated.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays.
px, py, pz	Input	The x, y, z coordinates of point "p". Size np. The center of the sphere with radius rsph.
rcir	Output	The radius of any circle of intersection centered at point "c". Size np. Positive if intersection occurs, zero if tangency occurs, negative if no intersection or tangency occurs, or if itrn = 2 or 3.

reph Input The radius of the sphere centered at point "p".
 Size np. The absolute value is used.

tol Input Numerical tolerance limit.
 On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTPTIC

```
call aptptic (pu, pv, au, av, bu, bv, np, tol, noptfd,  
             dpmn, fdmin, nlim, itrn, nerr)
```

Version: aptptic Updated 1990 February 14 13:00.
 aptptic Originated 1989 December 29 16:40.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe: aptblibe aptptic: end / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of np sets of input data, the minimum distance
 dpmn from the point p = (pu, pv) to the straight line through
 the points a = (au, av) and b = (bu, bv). All points are in
 the uv plane. Directions u, v and w are orthogonal.

Option noptfd allows the fractional distance fdmin of the
proximal point along line "ab" to be calculated, and allows
the range of fdmin to be limited. Flag nlim indicates
when such limitation has been imposed. If nlim = 2, dpmn is
the distance from point "p" to the nearest end of line
segment "ab".

The value of dpmn will be truncated to zero if less than the
estimated error in its calculation, based on tol, and if so,
itrn = 1 will be returned.

If the points "a" and "b" coincide, based on tol, dpmn will be
the distance from point "a" to point "p", and if dpmn is not
zero, itrn will be -1.

Flag nerr indicates any input error.

History: 1990 February 12 15:20. Added input argument noptfd,
optional output arguments fdmin, nlim.

Input: pu, pv, au, av, bu, bv, np, tol, noptfd.

Output: dpmn, fdmin, nlim, itrn, nerr.

Calls: aptfdav, aptvaxc, aptvdic, aptvdoc (sources in aptslibe,
binaries in aptblibe).

Glossary:

au, av	Input	The u and v coordinates of point "a" on line "ab". Size np. All points are in the uv plane.
bu, bv	Input	The u and v coordinates of point "b" on line "ab". Size np.
dpmn	Output	Distance from point "p" to the line "ab". Size np. Truncated to zero if less than the estimated error in its calculation, based on tol, and if so, itrn = 1 will be returned. If points "a" and "b" are coincident, dpmn is the distance from point "p" to point "a", and itrn = -1 is returned, unless dpmn = 0.0. If noptfd is 2, and fdmin is initially not in the range from 0.0 to 1.0, dpmn is the distance from point "p" to the nearest of points "a" and "b", and nlim = 2 is returned. The value of dpmn is positive, if point "p" is to the left of the vector "ab" in the uv plane.
fdmin	Output	Fractional distance between point "a" and point "b" of the point nearest point "p". See noptfd. Size np, if noptfd is not -1.
itrn	Output	0 if dpmn is not truncated to zero. Size np. 1 if dpmn is truncated to zero, when less than its estimated error, based on tol. -1 if dpmn is not zero, and points "a" and "b" coincide, based on tol.

nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 2 if noptfd is not -1, 0, 1, or 2.
nlim	Output	0 if no limit imposed on fdmin, 1 if the limit of noptfd = 1 is imposed, 2 if the limit of noptfd = 2 is imposed. Size np, if noptfd is not -1. If 2, dpmn is the distance from point "p" to the nearest end of line segment "ab".
noptfd	Input	Option to limit range of fdmin: 0 for no limit, -1 to not calculate fdmin or nlim. 0 to find fdmin, but impose no limits. 1 to increase fdmin to tol, if in the range from -tol to tol, and decrease fdmin to 1.0 - tol, if in the range from 1.0 - tol to 1.0 + tol. 2 to impose the limits for noptfd = 1, and then limit fdmin to the range from 0.0 to 1.0, and adjust the magnitude, but not the sign of dpmn if the later limit is imposed.
np	Input	Size of arrays pu, pv, au, av, bu, bv, itrn. If noptfd is not -1, the size of arrays fdmin, nlim.
pu, pv	Input	The u and v coordinates of point "p". Size np.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTPTLN

```
call aptptln (px, py, pz, ax, ay, az, bx, by, bz, np, tol,
             noptfd, dpmn, fdmin, cx, cy, cz, nlim, itrn, nerr)
```

Version: aptptln Updated 1990 February 14 10:00.
 aptptln Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LINL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibelx aptblibe aptptlnlend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of np sets of input data, the minimum distance dpmn from the point p = (px, py, pz) to the straight line through the points a = (ax, ay, az) and b = (bx, by, bz), to find the coordinates c = (cx, cy, cz) of the proximate point on line "ab", and to find the fractional distance fdmin of that point along the line segment "ab". The value of dpmn will be truncated to zero if less than the estimated error in its calculation, based on tol, and if so itrn = 1 will be returned. Flag nerr indicates any input error.

Option noptfd allows the line "ab" to be treated as a finite segment, by limiting the range of fdmin. Flag nlim indicates when such limitation has been imposed.

If the points "a" and "b" coincide, based on tol, dpmn will be the distance from point "a" to point "p", and if dpmn is not zero, itrn will be -1.

History: 1990 February 12 16:00. Fixed bug affecting fdmin when np is greater than 64.

Input: px, py, pz, ax, ay, az, bx, by, bz, np, tol, noptfd.

Output: dpmn, fdmin, cx, cy, cz, nlim, itrn, nerr.

Calls: aptfdav, aptvadd, aptvdis, aptvdot (sources in aptslibe, binaries in aptblibe).

Glossary:

ax,ay,az	Input	The x, y, z coordinates of point "a" on line "ab". Size np.
bx,by,bz	Input	The x, y, z coordinates of point "b" on line "ab". Size np.
cx,cy,cz	Output	The x, y, z coordinates of the point on the line "ab" nearest point "p". Point "p" if dpmn = 0. Size np.
dpmn	Output	Distance from point "p" to the line "ab". Size np. Truncated to zero if less than the estimated error in its calculation, based on tol, and if so, itrn = 1 will be returned. Perpendicular distance, unless itrn = -1, or nlim = 2.
fdmin	Output	Fractional distance between point "a" and point "b" of the point "c". Size np.
itrn	Output	0 if dpmn is not truncated to zero. 1 if dpmn is truncated to zero, when less than its estimated error, based on tol. Size np. -1 if dpmn is not zero, and points "a" and "b" coincide, based on tol.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 2 if noptfd is not 0, 1, or 2.
nlim	Output	0 if no limit imposed on fdmin, 1 if the limit of noptfd = 1 is imposed, 2 if the limit of noptfd = 2 is imposed. Size np. If the latter limit is imposed, dpmn will be the distance from point "p" to the nearest end of the line segment.

noptfd Input Option to limit range of fadmin: 0 for no limit;
1 to increase fadmin to tol, if in the range from
-tol to tol, and decrease fadmin to 1.0 - tol, if
in the range from 1.0 - tol to 1.0 + tol; and
2 to impose the limits for noptfd = 1, and then
limit fadmin to the range from 0.0 to 1.0.

np Input Size of arrays px, py, pz, ax, ay, az, bx, by, bz,
cx, cy, cz, fadmin, itrunc.

px,py,pz Input The x, y, z coordinates of point "p". Size np.

tol Input Numerical tolerance limit.
On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTPTPL

```
call aptptpl (px, py, pz, ax, ay, az, bx, by, bz, np, tol,
             dpmn, cx, cy, cz, itrn, nerr)
```

Version: aptptpl Updated 1990 March 15 11:50.
 aptptpl Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe!x aptblibe aptptplend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of np sets of input data, the minimum distance dpmn to the point p = (px, py, pz), from the plane through the point a = (ax, ay, az) with normal vector b = (bx, by, bz), and the coordinates c = (cx, cy, cz) of the point in the plane nearest point "p".
 Flag itrn indicates truncation of dpmn to zero (1) or too small a magnitude of vector "b" (2).
 Flag nerr indicates any input error.

History: 1990 March 14. Changed tol to 0.0 in call to unit vector subroutine. Allows small magnitudes.

Input: px, py, pz, ax, ay, az, bx, by, bz, np, tol.

Output: dpmn, cx, cy, cz, itrn, nerr.

Calls: aptvadd, aptvdis, aptvdot, aptvunb (sources in aptslibe, binaries in aptblibe).

Glossary:

ax,ay,az	Input	The x, y, z coordinates of point "a" in the plane. Size np.
bx,by,bz	Input	The x, y, z components of vector "b" normal to the plane. Magnitude must exceed tol. Size np.
cx,cy,cz	Output	The x, y, z coordinates of the point in the plane nearest point "p". Size np. Returned as point "p" if normal vector "b" is too short, based on tol (itrn = 2).
dpmn	Output	The perpendicular distance to point "p" from the plane through point "a" with normal vector "b". Positive if point "p" is in the same direction from the plane as the normal vector "b". Truncated to zero if less than the estimated error in its calculation, based on tol (itrn = 1). Returned as zero if normal vector "b" is too short, based on tol (itrn = 2).
itrn	Output	Indicates a special result for one data set: 1 if the value of dpmn is truncated to zero, when less than the estimated error in its calculation, based on tol. 2 if normal vector "b" is too short, based on tol. The orientation of the plane is unknown, and dpmn and point "c" cannot be calculated.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays.
px,py,pz	Input	The x, y, z coordinates of point "p". Size np.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTQDIC

```

call aptqdic (au, av, bu, bv, cu, cv, du, dv,
&            pu, pv, np, tol,
&            pab, pbc, pcd, pda, dpmn, nerr)

```

Version: aptqdic Updated 1990 February 21 11:00.
 aptqdic Originated 1990 February 21 11:00.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe(x aptblibe aptqdiclend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, the distances pab, pbc, pcd and pda from the point p = (pu, pv) to the sides of the quadrangle with vertices a = (au, av), b = (bu, bv), c = (cu, cv), and d = (du, dv), in counterclockwise order in the uv plane, and the minimum dpmn of pab, pbc, pcd and pda. The values of pab, pbc, pcd and pda will be truncated to zero, if less than the estimated error in their calculation, based on tol. Flag nerr indicates any input error.

Input: au, av, bu, bv, cu, cv, du, dv, pu, pv, np, tol.

Output: pab, pbc, pcd, pda, dpmn, nerr.

Calls: aptptlc (source in aptslibe, binary in aptblibe).

Glossary:

au, av	Input	The u, v coordinates of vertex "a" of the quadrangle. Size np.
bu, bv	Input	The u, v coordinates of vertex "b" of the quadrangle. Size np.
cu, cv	Input	The u, v coordinates of vertex "c" of the quadrangle. Size np.
dpmn	Output	Minimum of absolute values of distances pab, pbc, pcd and pda. Size np.
du, dv	Input	The u, v coordinates of vertex "d" of the quadrangle. Size np.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays pu, pv, au, av, bu, bv, cu, cv, du, dv, pab, pbc, pcd, pda.
pab	Output	Distance from point "p" to quadrangle side "ab". Truncated to zero, if less than the estimated error in its calculation, based on tol. Absolute value.
pbc	Output	Distance from point "p" to quadrangle side "bc". Truncated to zero, if less than the estimated error in its calculation, based on tol. Absolute value.
pcd	Output	Distance from point "p" to quadrangle side "cd". Truncated to zero, if less than the estimated error in its calculation, based on tol. Absolute value.
pda	Output	Distance from point "p" to quadrangle side "da". Truncated to zero, if less than the estimated error in its calculation, based on tol. Absolute value.
pu, pv	Input	The u and v coordinates of point "p" in the uv plane. Size np.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTQFDC

call aptqfdc (au, av, bu, bv, cu, cv, du, dv, pu, pv, np, tol,
 & fdk, fdl, ngood, nerr)

Version: aptqfdc Updated 1990 February 14 16:00.
 aptqfdc Originated 1990 February 14 16:00.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read ,245100:aptslibe / 1 1
 lib aptslibeix aptblibe aptqfcdlend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np points p = (pu, pv), the fractional
 distances fdk and fdl of point "p" between the opposite edges
 "da" and "bc", and "ab" and "cd", respectively, of the 2-D
 quadrilateral in the uv plane with vertices a = (au, av),
 b = (bu, bv), c = (cu, cv), and d = (du, dv).
 Flag nerr indicates any input error.

Input: au, av, bu, bv, cu, cv, du, dv, pu, pv, np, tol.

Output: fdk, fdl, ngood, nerr.

Calls: aptqrtv (source in aptslibe, binary in aptblibe).

Glossary:

au, av	Input	The u and v coordinates of point "a" in the uv plane.
bu, bv	Input	The u and v coordinates of point "b" in the uv plane.
cu, cv	Input	The u and v coordinates of point "c" in the uv plane.
du, dv	Input	The u and v coordinates of point "d" in the uv plane.
fdk	Output	Fractional distance of point "p" from the line segment "da" to the line segment "bc". Size np. Values between -tol and tol will be adjusted to tol. Values between 1.0 - tol and 1.0 + tol will be adjusted to 1.0 - tol. See ngood.
fdl	Output	Fractional distance of point "p" from the line segment "ab" to the line segment "cd". Size np. Values between -tol and tol will be adjusted to tol. Values between 1.0 - tol and 1.0 + tol will be adjusted to 1.0 - tol. See ngood.
ngood	Output	Indicates range of fractional distances fdk and fdl: 0 if either fdk or fdl is outside the range from -tol to 1.0 + tol. Also if both are. 1 if fdk and fdl are both between -tol and 1.0 + tol. This can be true even when point "p" is outside a boomeranged or bowtied quadrangle. 2 if fdk and fdl are both between -tol and 1.0 + tol, and two possible solutions exist. This can happen when the quadrangle is a boomerang or bowtie. Only one of the solutions is returned.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays pu, pv, fdk, fdl.
pu, pv	Input	The u and v coordinates of point "p" in the uv plane. Size np.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTQINC

```

call aptqinc (ktype, ntype, au, av, bu, bv, cu, cv, du, dv,
& pu, pv, np, tol,
& pab, pbc, pcd, pda, dpmin, nloc, nerr)

```

Version: aptqinc Updated 1990 February 21 16:40.
 aptqinc Originated 1990 February 21 16:40.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe|x aptblibe aptqinc|end / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, the distances pab, pbc, pcd and pda from the point p = (pu, pv) to the sides of the quadrangle with vertices a = (au, av), b = (bu, bv), c = (cu, cv), and d = (du, dv), in counterclockwise order in the uv plane, the minimum dpmin of pab, pbc, pcd and pda, and whether point "p" is inside the quadrangle or not (flag nloc). Option kflag allows the quadrangle shape type to be ignored, output, or input, and boomerangs and bowties to be tested. The values of pab, pbc, pcd and pda will be truncated to zero, if less than the estimated error in their calculation, based on tol. Flag nerr indicates any input error.

Input: ktype, ntype, au, av, bu, bv, cu, cv, du, dv, pu, pv, np, tol.

Output: pab, pbc, pcd, pda, dpmin, nloc, nerr.

Calls: aptptlc, aptqvac (sources in aptslibe, binaries in aptblibe).

Glossary:

au, av	Input	The u, v coordinates of vertex "a" of the quadrangle. Size np.
bu, bv	Input	The u, v coordinates of vertex "b" of the quadrangle. Size np.
cu, cv	Input	The u, v coordinates of vertex "c" of the quadrangle. Size np.
dpmin	Output	Minimum of distances pab, pbc, pcd, pda. Size np. Minimum of absolute values of pab, pbc, pcd, pda, if point "p" is in a boomerang or bowtie, and ktype = 0, 1 or 2. Negative if nloc = 0.
du, dv	Input	The u, v coordinates of vertex "d" of the quadrangle. Size np.
ktype	Input	Indicates whether ntype is input or output, and whether or not cases for which nloc is initially zero will be tested to see if the point is actually inside a boomerang or bowtie. -1 if ntype is not input, and is not to be returned. No tests will be made for boomerangs or bowties. 0 if ntype is not input, and is not to be returned. Tests will be made for boomerangs and bowties. 1 if ntype is not input, but will be returned. Tests will be made for boomerangs and bowties. 2 if ntype is input. Tests will be made for boomerangs and bowties.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 2 if ktype is not -1, 0, 1 or 2.

nloc	Output	Indicates the location of point "p" relative to the quadrangle "abcd": -1 if all quadrangle vertices coincide. 0 if point "p" is outside the quadrangle "abcd", or is inside, but the quadrangle vertices were specified in clockwise order, or if ktype = -1, is inside a bowtie or in certain areas inside a boomerang. 1 if point "p" is inside the quadrangle "abcd", and either all four distances pab, pbc, pcd and pda are non-negative, or if ktype = 0, 1 or 2, the quadrangle is a boomerang or bowtie and the distances pass specific tests.
np	Input	Size of arrays pu, pv, au, av, bu, bv, cu, cv, du, dv, pab, pbc, pcd, pda.
ntype	I/O?	Shape type of quadrangle. Input if ktype = 2. Output if ktype = 1. Size np if ktype = 1 or 2. 0 if quadrangle is convex. 11-14 if quadrangle has just one concave vertex at point "a", "b", "c", or "d", resp. (a boomerang). 21-24 if quadrangle has just two adjacent concave vertices at ends of sides "cd", "da", "ab", or "bc", respectively (a bowtie).
pab	Output	Distance from point "p" to quadrangle side "ab". Truncated to zero, if less than the estimated error in its calculation, based on tol.
pbc	Output	Distance from point "p" to quadrangle side "bc". Truncated to zero, if less than the estimated error in its calculation, based on tol.
pcd	Output	Distance from point "p" to quadrangle side "cd". Truncated to zero, if less than the estimated error in its calculation, based on tol.
pda	Output	Distance from point "p" to quadrangle side "da". Truncated to zero, if less than the estimated error in its calculation, based on tol.
pu, pv	Input	The u and v coordinates of point "p" in the uv plane. Size np.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTQLOC

```
call aptqloc (au, av, bu, bv, cu, cv, du, dv, np, tol,
             fdk, fdl, pu, pv, nerr)
```

Version: aptqloc Updated 1990 February 14 17:30.
 aptqloc Originated 1990 February 8 14:30.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe!x aptblibe aptqloc!end / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find np points $p = (pu, pv)$, by sampling from a uniform distribution over the planar quadrangle in the uv plane, with vertices $a = (au, av)$, $b = (bu, bv)$, $c = (cu, cv)$, $d = (du, dv)$, in counterclockwise order around the quadrangle. For a triangle, make $du = au$, $dv = av$, or call apttloc. If the quadrangle has a non-positive area, no points will be sampled.

Variables fdk and fdl are the local coordinates in the quadrangle. For any point $p = (pu, pv)$ in the quadrangle:

$$\begin{aligned} pu &= au + fdk * (bu - au) + fdl * (du - au) + \\ &\quad fdk * fdl * (au - bu + cu - du) \\ pv &= av + fdk * (bv - av) + fdl * (dv - av) + \\ &\quad fdk * fdl * (av - bv + cv - dv) \end{aligned}$$

Given $p = (pu, pv)$, fdk and fdl may be found by calling subroutine aptqfdc.

Flag nerr indicates any input error.

History: 1990 February 14 17:30. Added capability to sample from boomerangs and bowties.

Input: au, av, bu, bv, cu, cv, du, dv, np, tol.

Output: fdk, fdl, pu, pv, nerr.

Calls: aptqfdc, aptqvac, aptslid, aptsliv, apttloc
 (sources in aptslibe, binaries in aptblibe).

Glossary:

au, av	Input	The u and v coordinates of vertex "a" of quadrangle.
bu, bv	Input	The u and v coordinates of vertex "b" of quadrangle.
cu, cv	Input	The u and v coordinates of vertex "c" of quadrangle.
du, dv	Input	The u and v coordinates of vertex "d" of quadrangle.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 2 if quadrangle area is not positive (no sampling).
np	Input	Size of arrays fdk, fdl, pu, pv. Number of points "p" to sample.
fdk	Output	Fractional distance of point "p" between the quadrangle sides "da" and "bc". Range 0.0 to 1.0. Size np. Range may be less in a boomerang or bowtie.
fdl	Output	Fractional distance of point "p" between the quadrangle sides "ab" and "cd". Range 0.0 to 1.0. Size np. Range may be less in a boomerang or bowtie.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.
pu, pv	Output	Sampled points. Size np.

SUBROUTINE APTQRTS

```
call aptqrts (noptq, aa, bb, cc, qq, tol,
             roots, root1, root2, itrunc)
```

Version: aptqrts Updated 1990 March 21 14:00.
 aptqrts Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe|x aptblibe aptqrts!end / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find any real roots of the quadratic equation:

$$aa * x^2 + bb * x + cc = 0.$$

The method minimizes truncation error, and indicates when truncation error may still be significant, based on tol. Option noptq allows the user to specify the value of $qq = bb^2 - 4.0 * aa * cc$, instead of using the value calculated here.

Note: aptqrvtv is a vectorized version of aptqrts.

History: 1990 March 21 14:00. Changed to truncate small positive values of qq to zero.

Input: noptq, aa, bb, cc, qq, tol.

Output: qq, roots, root1, root2, itrunc.

Glossary:

aa	Input	Coefficient of x^2 in a quadratic equation.
bb	Input	Coefficient of x in a quadratic equation.
cc	Input	Coefficient of 1 in a quadratic equation.
itrunc	Output	Truncation error indicator. 0 if insignificant. 1 if the magnitude of qq is less than the estimated truncation error, based on tol. This indicates that the roots are near a minimum or maximum, or that the quadratic is almost the square of a linear function. The value of qq is truncated to zero. 2 if the input value of qq (noptq = 1) differs from the calculated value by more than the estimated truncation error, based on tol.
noptq	Input	Option for getting value of $qq = bb^2 - 4.0 * aa * cc$: 0 to not use input qq, but calculate from aa, bb, cc. 1 to use the input value of qq (more accurate). A nonzero value of tol must be used with this option, for comparison of the input with the calculated value.
roots	Output	Number of real roots: -1 if ((aa .eq. 0.0) .and. (bb .eq. 0.0)). Equation is null (cc .eq. 0.) or bad (cc .ne. 0.). 0 if (bb**2 .lt. 4.0 * aa * cc). Roots are complex. 1 if equation is linear: (aa .eq. 0.0) .and. (bb .ne. 0.0), or if qq = 0.0. 2 if (bb**2 .gt. 4.0 * aa * cc).
qq	Input	If noptq = 1. Equal to $qq = bb^2 - 4.0 * aa * cc$, but calculated more accurately, due to cancellation of terms resulting from the composite nature of aa, bb, and/or cc.
qq	Output	If noptq = 0. Equal to $qq = bb^2 - 4.0 * aa * cc$, calculated locally.

root1 Output The first or only real root, if (nroots .ge. 1).
root2 Output The second real root, if (nroots .eq. 2).
tol Input Numerical tolerance limit.
Must not be zero if noptq = 1.
On Cray computers, recommend 1.e-8 to 1.e-11.

SUBROUTINE APTQRTV

```
call aptqrtv (noptq, aa, bb, cc, qq, np, tol,
nroots, root1, root2, itrunc)
```

Version: aptqrtv Updated 1990 March 21 14:00.
 aptqrtv Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read ,245100:aptslibe / 1 1
 lib aptslibe;x aptblibe aptqrtv:lend / 1 1.
 aptslibe is a LIB library of FORTRAN source files,
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find any real roots of the quadratic equation:

$$aa * x^{**2} + bb * x + cc = 0.$$

for np sets of coefficients aa, bb, cc.
 The solution is vectorized over the sets of coefficients,
 which are calculated in sections of 64 (or less, for the
 final section).
 The method minimizes truncation error, and indicates when
 truncation error may still be significant, based on tol.
 Option noptq allows the user to specify the value of
 $qq = bb^{**2} - 4.0 * aa * cc$, instead of using the value
 calculated here.

Note: aptqrts is a scalar version of aptqrtv.

History: 1990 January 19 15:00. Fixed bug for a = 0.0 or b = 0.0.
 1990 March 21 14:00. Changed to allow truncation of small
 positive qq to zero.

Input: noptq, aa, bb, cc, qq, np, tol.

Output: qq, nroots, root1, root2, itrunc.

Glossary:

- | | | |
|--------|--------|---|
| aa | Input | Coefficients of x^{**2} in a quadratic equation. Size np. |
| bb | Input | Coefficients of x in a quadratic equation. Size np. |
| cc | Input | Coefficients of 1 in a quadratic equation. Size np. |
| itrunc | Output | Truncation error indicator. 0 if insignificant.
1 if the magnitude of qq is less than the estimated
truncation error, based on tol. This indicates
that the roots are near a minimum or maximum, or
that the quadratic is almost the square of a linear
function. The value of qq is truncated to zero.
2 if the input value of qq (noptq = 1) differs from
the calculated value by more than the estimated
truncation error, based on tol.
Size np. |
| nerr | Output | Indicates an input error, if not 0.
i if np is not positive. |
| noptq | Input | Option for getting value of $qq = bb^{**2} - 4.0 * aa * cc$:
0 to not use input qq, but calculate from aa, bb, cc.
1 to use the input value of qq (more accurate).
A nonzero value of tol must be used with this
option, for comparison of the input with the
calculated value. |
| nroots | Output | Number of real roots:
-1 if ((aa .eq. 0.0) .and. (bb .eq. 0.0)).
Equation is null (cc .eq. 0.) or bad (cc .ne. 0.).
0 if (bb**2 .lt. 4.0 * aa * cc).
Roots are complex.
1 if equation is linear:
(aa .eq. 0.0) .and. (bb .ne. 0.0),
or if qq = 0.0.
2 if (bb**2 .gt. 4.0 * aa * cc).
Size np. |
| np | Input | Number of sets of input data aa, bb, cc, noptq, qq. |

SUBROUTINE APTQUAD

```

call aptquad (px, py, pz, ax, ay, az, bx, by, bz,
4          cx, cy, cz, dx, dy, dz, noptfd, tol,
4          dpmin, fdkq, fdli, qx, qy, qz,
4          nlimk, nliml, itrunc, nside, ncon, nerr)

```

Version: aptquad Updated 1989 November 29 16:10.
 aptquad Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe: aptblibe aptquadlend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the minimum distance dpmin from the external point p = (px, py, pz), to the surface bounded by a 3-D quadrangle with vertices (ax, ay, az), (bx, by, bz), (cx, cy, cz), (dx, dy, dz); to find the point q = (qx, qy, qz) on the surface nearest the external point; and to find the fractional distances fdkq and fdli of that point between opposite sides of the quadrangle. Option noptfd allows the ranges of fdkq and fdli to be limited. Result and error flags are returned.

The equation of the surface (r, a, b, c, d are vectors) is:

$$r = a + (b - a) * fdk + (d - a) * fdli + (a - b + c - d) * fdk * fdli$$

$$r = a * (1 - fdk) * (1 - fdli) + b * fdk * (1 - fdli) + c * fdk * fdli + d * (1 - fdk) * fdli$$

where r is a vector (x, y, z), and fdk, fdli are fractional distances between opposite edges.

Method: Uses functional iteration, tangent plane approximation, and acceleration. The rate of convergence depends on the problem. For 2 initial values of fdk, iteratively find fdli nearest the external point, the best fdk for that fdli, etc. If two minima are found, use the least value of dpmin.

Input: px, py, pz, ax, ay, az, bx, by, bz, cx, cy, cz, dx, dy, dz, tol,

Output: dpmin, fdkq, fdli, qx, qy, qz, nlimk, nliml, itrunc, ncon, nerr.

Calls: aptfdad, aptptln, aptptpl, aptvdis, aptvpin (sources in aptslibe, binaries in aptblibe).

Glossary:

ax, ay, az	Input	The x, y, z coordinates of quadrangle vertex "a".
bx, by, bz	Input	The x, y, z coordinates of quadrangle vertex "b".
cx, cy, cz	Input	The x, y, z coordinates of quadrangle vertex "c".
dx, dy, dz	Input	The x, y, z coordinates of quadrangle vertex "d".
dpmin	Output	Minimum distance from point p = (px, py, pz) to the surface bounded by the edges of the 3-D quadrangle with vertices (ax, ay, az), (bx, by, bz), (cx, cy, cz) and (dx, dy, dz).
fdkq	Output	Fractional distance of the point q = (qx, qy, qz) between opposite edges of the quadrangle, from the edge bounded by (ax, ay, az) and (dx, dy, dz). A value of exactly 0.0 or 1.0 may indicate actual minimum point outside quadrangle. Values within tol of 0.0 or 1.0 may be shifted slightly inside quadrangle. See nlimk.

fdlq	Output	Fractional distance of the point $q = (qx, qy, qz)$ between opposite edges of the quadrangle, from the edge bounded by (ax, ay, az) and (bx, by, bz) . A value of exactly 0.0 or 1.0 may indicate actual minimum point outside quadrangle. Values within tol of 0.0 or 1.0 may be shifted slightly inside quadrangle. See nliml.
itrn	Output	0 if no change is made in the calculated value of $dpmin$, 1 if $dpmin$ is changed to zero, when less than the estimated error in its calculation.
ncon	Output	Error flag. 1 or 2 if first two guesses fail to converge. 3 for total failure to find solution.
nerr	Output	Indicates an input error, if not 0. 1 is added if noptfd is not between 0 and 2.
nlimk	Output	0 if fdkq not adjusted. 1 if near 0.0 or 1.0, shifted inside quadrangle. 2 if outside range 0.0 to 1.0, shifted to 0.0 or 1.0.
nliml	Output	0 if fdlq not adjusted. 1 if near 0.0 or 1.0, shifted inside quadrangle. 2 if outside range 0.0 to 1.0, shifted to 0.0 or 1.0.
noptfd	Input	Option to limit the ranges of fdkq, fdlq: 0 for no limit, 1 to increase to tol, if in the range from -tol to tol, and decrease to $1.0 - tol$, if in the range from $1.0 - tol$ to $1.0 + tol$ (move a point near an edge slightly inside the quadrangle), and 2 to limit to the range from 0.0 to 1.0 (move a point outside the triangle to an edge).
nside	Output	1 if the point nearest $p = (px, py, pz)$ in the extended surface through the quadrangle is actually $q = (qx, qy, qz)$, within tolerance tol. 0 if $q = (qx, qy, qz)$ is only the point on the edges of the quadrangle nearest (px, py, pz) , but the vector connecting "p" to "q" is not normal to the surface.
px,py,pz	Input	The x, y, z coordinates of the external point "p".
qx,qy,qz	Output	The x, y, z coordinates of the point "q" nearest to $p = (px, py, pz)$ on the biquadratic surface.
tol	Input	Numerical tolerance limit. Convergence criterion for $dpmin$. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTQVAC

```
call aptqvac (au, av, bu, bv, cu, cv, du, dv, np, tol, nopt,
             arpa, arpb, arpc, arpd, ntype, qu, qv, nerr)
```

Version: aptqvac Updated 1990 February 13 13:00.
 aptqvac Originated 1990 February 8 14:00.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe|x aptslibe aptqvac|end / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptslibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the shape and size of np quadrangles in the uv plane, with vertices a = (au, av), b = (bu, bv), c = (cu, cv) and d = (du, dv) counterclockwise around the quadrangle. Optionally (nopt = 0 or 2), the vertex parallelogram areas arpa, arpb, arpc and arpd will be returned, and (nopt = 1 or 2) the number and location of any concave (negative area) vertices will be returned, encoded in ntype, and if the quadrangle is a bowtie, the intersection of the sides q = (qu, qv), will be returned. The net area of the quadrangle is 0.25 * (arpa + arpb + arpc + arpd). Flag nerr indicates any input error.

Input: au, av, bu, bv, cu, cv, du, dv, np, tol, nopt.

Output: ntype, arpa, arpb, arpc, arpd, nerr.

Calls: aptvdlc, aptvaxc
 (sources in aptslibe, binaries in aptslibe).

Glossary:

arpa	Output	Parallelogram area at vertex "a" (nopt = 0 or 2). Size np.
arpb	Output	Parallelogram area at vertex "b" (nopt = 0 or 2). Size np.
arpc	Output	Parallelogram area at vertex "c" (nopt = 0 or 2). Size np.
arpd	Output	Parallelogram area at vertex "d" (nopt = 0 or 2). Size np.
au, av	Input	The u and v coordinates of vertex "a" of quadrangle. Size np.
bu, bv	Input	The u and v coordinates of vertex "b" of quadrangle. Size np.
cu, cv	Input	The u and v coordinates of vertex "c" of quadrangle. Size np.
du, dv	Input	The u and v coordinates of vertex "d" of quadrangle. Size np.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 2 if nopt is not 0, 1 or 2.
nopt	Input	Output option: 0 or 2 to return vertex parallelogram areas. 1 or 2 to return shape type code ntype. 2 to return areas, ntype, and bowtie intersections.
np	Input	Size of arrays au, av, bu, bv, cu, cv, du, dv, and if nopt = 0 or 2, arpa, arpb, arpc and arpd, and if nopt = 1 or 2, ntype.

n _{type}	Output	Shape type of quadrangle (nopt = 1 or 2). 0 if all vertices are convex. Regular. 11 if only vertex "a" is concave. Boomerang. 12 if only vertex "b" is concave. Boomerang. 13 if only vertex "c" is concave. Boomerang. 14 if only vertex "d" is concave. Boomerang. 21 if only vertices "c" and "d" are concave. Bowtie. 22 if only vertices "d" and "a" are concave. Bowtie. 23 if only vertices "a" and "b" are concave. Bowtie. 24 if only vertices "b" and "c" are concave. Bowtie. 31 if only vertex "a" is convex. Inverted boomerang. 32 if only vertex "b" is convex. Inverted boomerang. 33 if only vertex "c" is convex. Inverted boomerang. 34 if only vertex "d" is convex. Inverted boomerang. 40 if all vertices are concave. Inverted regular.
qu, qv	Output	The u and v coordinates of the intersection "q" of two opposite sides of a bowtied quadrangle. Returned only if nopt = 1 or 2, and n _{type} = 21 to 24.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTREFC

call aptrefc (pu, pv, au, av, bu, bv, np, tol, qu, qv, nerr)

Version: aptrefc Updated 1990 March 13 11:30.
aptrefc Originated 1990 January 10 13:50.

Author: Arthur L. Edwards, LINL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe;x aptblibe aptrefclend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of np sets of input data, the 2-D vector $q = (qu, qv)$ resulting from the reflection of the 2-D vector $p = (pu, pv)$ from the line through the points $a = (au, av)$ and $b = (bu, bv)$, all in the uv plane. When point "a" coincides with point "b", based on tol, no reflection takes place, and vector "q" equals vector "p". Coordinates u and v may be any orthogonal coordinates. Flag nerr indicates any input error.

Method: The vector "sn" normal to the reflecting surface is the cross product of the vector normal to the uv plane, (0, 0, 1), and the vector parallel to the line "ab". From simple geometry, $q = p - 2.0 * (p \cdot u) * u$, where "u" is the unit vector parallel to "sn".

Input: pu, pv, au, av, bu, bv, np, tol.

Output: qu, qv, nerr.

Glossary:

au, av	Input	The u and v coordinates of point "a" in the uv plane. Must differ from "b", based on tol. Size np.
bu, bv	Input	The u and v coordinates of point "b" in the uv plane. Must differ from "a", based on tol. Size np.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays.
pu, pv	Input	The u and v components of the incident vector "p". Size np.
qu, qv	Output	The u and v components of the reflected vector "q". Components of "q" less than the estimated error in their calculation, based on tol, will be truncated to zero. Size np.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTREFL

```
call aptrefl (pu, pv, pw, au, av, bu, bv, np, tol,
             qu, qv, qw, nerr)
```

Version: aptrefl Updated 1990 March 13 11:30.
 aptrefl Originated 1990 January 10 13:50.

Author: Arthur L. Edwards, LNL, L-298, Telephone (415) 422-4123,

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe|x aptblibe aptrefl|end / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of np sets of input data, the vector $q = (qu, qv, qw)$ resulting from the reflection of vector $p = (pu, pv, pw)$ from the surface perpendicular to the uv plane and through the points $a = (au, av, 0)$, and $b = (bu, bv, 0)$, when incident on the surface on the line "ab". When point "a" coincides with point "b", based on tol, no reflection takes place, and vector "q" equals vector "p". Coordinates u, v and w may be any orthogonal coordinates. Flag nerr indicates any input error.

Method: The vector "sn" normal to the reflecting surface is the cross product of the vector normal to the uv plane, (0, 0, 1), and the vector parallel to the line "ab". From simple geometry, $q = p - 2.0 * (p \cdot u) * u$, where "u" is the unit vector parallel to "sn".

Input: pu, pv, pw, au, av, bu, bv, np, tol.

Output: qu, qv, qw, nerr.

Glossary:

- | | | |
|------------|--------|---|
| au, av | Input | The u and v coordinates of point "a" in the uv plane. Must differ from "b", based on tol. Size np. |
| bu, bv | Input | The u and v coordinates of point "b" in the uv plane. Must differ from "a", based on tol. Size np. |
| nerr | Output | Indicates an input error, if not 0.
1 if np is not positive. |
| np | Input | Size of arrays. |
| pu, pv, pw | Input | The u, v, w components of incident vector "p".
Size np. |
| qu, qv, qw | Output | The u, v, w components of reflected vector "q".
Components of "q" less than the estimated error in their calculation, based on tol, will be truncated to zero.
Note that $qw = pw$. Size np. |
| tol | Input | Numerical tolerance limit.
On Cray computers, recommend 1.e-5 to 1.e-11. |

SUBROUTINE APTREFS

```
call aptrefs (itype, ax, ay, az, bx, by, bz, cx, cy, cz,
             px, py, pz, np, tol, refm, nerr)
```

Version: aptrefs Updated 1990 March 14 16:00.
 aptrefs Originated 1990 January 10 13:50.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe|x aptblibe aptrefslend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the matrix operator refm for reflection from a plane:
 itype = 0: the plane contains point a = (ax, ay, az), and
 has normal vector b = (bx, by, bz).
 itype = 1: the reflection exchanges the points a = (ax, ay, az)
 and (bx, by, bz).
 itype = 2: the plane contains the 3 points a = (ax, ay, az),
 b = (bx, by, bz), and c = (cx, cy, cz).

To do the reflection operation on the np points
 or vectors p = (px, py, pz). If p = (px, py, pz) are unbound
 vectors, either use module aptmopv, or make sure the reflection
 plane contains the origin. Size np may be 0.
 The new values of (px, py, pz) will be truncated to zero
 if less than the estimated error in their calculation,
 based on tol.

History: 1990 March 14. Changed tol to 0.0 in call to unit vector
 subroutine. Allows small magnitudes.

Input: itype, ax, ay, az, bx, by, bz, cx, cy, cz, px, py, pz, np, tol.

Output: px, py, pz, refm, nerr.

Calls: aptvxun, aptvunb (sources in aptslibe,
 binaries in aptblibe).

Glossary:

ax,ay,az	Input	The x, y, z coordinates or components of a point or vector.
bx,by,bz	Input	The x, y, z coordinates or components of a point or vector.
cx,cy,cz	Input	The x, y, z coordinates of a point.
itype	Input	Defines option for describing reflection plane: 0 if plane contains point a = (ax, ay, az), and and has normal vector b = (bx, by, bz). 1 if reflection exchanges (ax, ay, az), (bx, by, bz). 2 if plane contains points (ax, ay, az), (bx, by, bz) and (cx, cy, cz).
nerr	Output	Indicates an input error, if not 0. 1 if the magnitude of any input vector is too small, 2 if any 2 of the points (a, b, c) are congruent, or if the points (a, b, c) are colinear, and itype = 3. 3 if itype is not 0, 1 or 2.
np	Input	Number of points or vectors (px, py, pz). May be 0.
px,py,pz	In/Out	The x, y, z coordinates of a point, or the x, y, z components of a vector. Size np. Will be truncated to zero, if less than the estimated error in their calculation, based on tol.
refm	Output	Reflection operator (a unitary 3 x 3 matrix). Must be sized refm(3,3).
tol	Input	Numerical tolerance limit. Used to test and adjust unit vector and point components. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTRKCL

call aptrkcl (pr, ur, ut, uz, sr, dr, dintmn, dintmx, np, tol,
nint, dint, nerr)

Version: aptrkcl Updated 1990 January 24 13:40.
aptrkcl Originated 1990 January 19 16:20.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptrkcl|end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, any exit intersection of the linear track through point p = (pr) with unit direction vector u = (ur, ut, uz), with the cylindrical surface with fixed radius sr, for which (1) the distance dint from point "p" to the intersection is between the limits dintmn and dintmx, and (2) the radial component ur of the direction vector "u" at the intersection has the same sign as dr. Flag nerr indicates any input error.

Input: pr, ur, ut, uz, sr, dr, dintmn, dintmx, np, tol.

Output: nint, dint, nerr.

Calls: aptqrv, aptvlim (aptdav optional)
(sources in aptslibe, binaries in aptblibe).

Glossary:

dint	Output	Distance from point "p" to intersection at radius sr along track (not radial distance).
dintmn	Input	Minimum allowed value of distance to intersection. Size np.
dintmx	Input	Maximum allowed value of distance to intersection. Size np.
dr	Input	Sign of exit direction through surface at sr. Size np.
nerr	Output	If not 0, indicates an input error. 1 if np is not positive.
nint	Output	0 if no exit intersection was found. 1 if an exit intersection was found at the surface at radius sr, with a distance to intersection dint between dintmn and dintmx. Size np.
np	Input	Size of arrays pr, ur, ut, uz, sr, dr, dintmn, dintmx, nint.
pr	Input	Cylindrical radial coordinate of initial point on track. Size np.
sr	Input	Cylindrical radial coordinate of surface. Size np.
ur	Input	Initial cylindrical radial component of unit direction vector along track. Size np.
ut	Input	Initial theta component of unit direction vector along track. Theta is angle in x-y plane counterclockwise from x axis. Size np.
uz	Input	Initial axial z component of unit direction vector along track. Size np.
tol	Input	Truncation error limit. Used to test for intersection being nearly tangent, and for accuracy of intersection. Must not be zero. On Cray computers, recommend 1.e-11.

SUBROUTINE APTRKCY

```

call aptrkcy (pz, pr, uz, ur, ut, az, ar, bz, br,
&            dintmn, dintmx, np, noptd, tolf, tols,
&            nint, pinz, pinr, dint, nerr)

```

Version: aptrkcy Updated 1990 January 23 16:30.
aptrkcy Originated 1989 December 7 16:40.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptrkcyend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, any acceptable exit intersection (pinz, pinr) of the linear track through point p = (pz, pr) with unit direction vector u = (uz, ur, ut), with the cylindrical axisymmetric surface through points a = (az, ar) and b = (bz, br), for which (1) the distance from point "p" to pin = (pinz, pinr) is between the limits dintmn and dintmx, (2) the intersection is between a = (az, ar) and b = (bz, br), and (3) the crossing at the intersection is from left to right in the zr plane (right to left in the rz plane). This is a zone exit if the points (az, ar) and (bz, br) are the vertices of a zone edge, counterclockwise around the zone in the the zr plane (clockwise in the rz plane).

History: 1990 January 23 10:10. Implemented use of aptfdav to adjust values of fint1 and fint2 near 0.0 or 1.0. Vectorized intersection test loop.

Input: pz, pr, uz, ur, ut, az, ar, bz, br, dintmn, dintmx, np, noptd, tolf, tols.

Output: nint, pinz, pinr, dint, nerr.

Calls: aptqrtv, aptvlim, aptfdav.
(Sources in aptslibe, binaries in aptblibe).

Glossary:

ar	Input	Cylindrical radial coordinate of beginning of cylindrical axisymmetric surface. Size np. Theta ranges from 0 to 360 degrees.
az	Input	Cylindrical axial z coordinate of beginning of cylindrical axisymmetric surface. Size np.
br	Input	Cylindrical radial coordinate of end of cylindrical axisymmetric surface. Size np.
bz	Input	Cylindrical axial z coordinate of end of cylindrical axisymmetric surface. Size np.
dint	Output	Distance from (pz, pr) to intersection at (pinz, pinr), along track (not distance in zr plane).
dintmn	Input	Minimum allowed value of distance to intersection. Size np.
dintmx	Input	Maximum allowed value of distance to intersection. Size np.
nerr	Output	If not 0, indicates an input error. 1 if np is not positive.
nint	Output	0 if no acceptable exit intersection was found. 1 if an acceptable exit intersection was found on the surface segment between (az, ar) and (bz, br), with a distance to the intersection dint between dintmn and dintmx. Size np.
noptd	Input	Option to limit the minimum magnitude of the components of the direction vector u = (uz, ur, ut). The method used here will fail if uz or ut is zero. 0 for no magnitude test. Must be done elsewhere. 1 to limit the minimum magnitudes of ut and uz to no less than tols.

np	Input	Size of arrays pz, pr, uz, ur, ut, az, ar, bz, br, dintmn, dintmx, nint, pinz, pinr.
pinr	Output	Cylindrical radial r coordinate of intersection point. Size np.
pinz	Output	Cylindrical axial z coordinate of intersection point. Size np.
pr	Input	Cylindrical radial r coordinate of the initial point on the track. Size np.
pz	Input	Axial z coordinate of the initial point on the track. Size np.
ur	Input	Initial cylindrical radial component of the unit direction vector along the track. Size np.
ut	Input	Initial theta component of the unit direction vector along the track. Theta is the angle in the xy plane counterclockwise from x axis. Size np.
uz	Input	Initial axial z component of unit direction vector along track. Size np.
tolf	Input	Truncation error limit to be imposed on the fractional distance of the intersection (pinz, pinr) along the line segment from (az, ar) to (bz, br). Values less than -tolf or greater than 1.0 + tolf will not be accepted. Values from -tolf to tolf will be changed to tolf. Values from 1.0 - tolf to 1.0 + tolf will be changed to 1.0 - tolf. Also used to test for the intersection being nearly tangent, and for the accuracy of the intersection. Must not be zero. On Cray computers, recommend 1.e-11.
tols	Input	Truncation error limit to be imposed on uz, ut and pinr. Magnitudes of ut and uz less than tols will be increased to tols. Values of pinr less than tols * pr will be increased to tols * pr. On Cray computers, recommend 1.e-5. A value of zero may produce unpredictable results.

SUBROUTINE APTRKIS

```

call aptrkis (px, py, pz, vx, vy, vz, ac, ax, ay, az,
4          axy, ayz, azx, axx, ayy, azz, dintmn, dintmx,
4          np, tol, nint, qx, qy, qz, dint, nerr)

```

Version: aptrkis Updated 1990 March 14 16:00.
aptrkis Originated 1990 February 23 10:00.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibelx aptblibe aptrkislend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of np sets of input data, the distance dint
to the intersection q = (qx, qy, qz) of the linear track through
point p = (px, py, pz) with direction vector v = (vx, vy, vz),
and the general second order surface for which the equation is

$$f(x,y,z) = ac + ax * x + ay * y + az * z + axy * x * y + ayz * y * z + azx * z * x + axx * x**2 + ayy * y**2 + azz * z**2 = 0,$$

and for which dint is between dintmn and dintmx. If two such intersections occur, the one with the smaller magnitude of dint will be returned. If no such intersection is found, nint will be 0, and dint and the coordinates of point "q" will be very large. Flag nerr indicates any input error.

The vector normal to the surface is s = (df/dx, df/dy, df/dz). The sign of the direction of the intersection is determined by the dot product v * s.

History: 1990 March 14. Changed tol to 0.0 in call to unit vector subroutine. Allows small magnitudes.

Input: px, py, pz, vx, vy, vz, ac, ax, ay, az, axy, ayz, azx, axx, ayy, azz, dintmn, dintmx, np, tol.

Output: nint, qx, qy, qz, dint, nerr.

Calls: aptqrv, aptvadd, aptvunb
(sources in aptslibe, binaries in aptblibe).

Glossary:

a...	Input	Coefficients of the implicit equation of a second-order surface in xyz space (ac, ax, ay, az, axy, ayz, azx, axx, ayy, azz).
dint	Output	The distance of the point of intersection "q" from point "p", if nint = 1. Size np. Positive if in the same direction as vector "v". Acceptable only if between dintmn and dintmx.
dintmn	Input	The minimum allowable value of dint.
dintmx	Input	The maximum allowable value of dint.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 1 if the track through point "p" in direction "v" intersects the surface at a distance dint between dintmn and dintmx. 0 if no such intersection was found. -1 if vector "v" is too short, based on tol.
np	Input	Size of arrays.
px,py,pz	Input	The x, y, z coordinates of point "p".
qx,qy,qz	Output	The x, y, z coordinates of the point of intersection of the line through point "p" with unit direction vector "v", and the surface, if nint = 1.

vx,vy,vz Input The x, y, z components of direction vector "v".
If the magnitude is too small, nint will be -1.

tol Input Numerical tolerance limit.
On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTRKLC

```

call aptrklc (au, av, abu, abv, cu, cv, du, dv,
4          dintmn, dintmx, np, tol,
4          nint, eu, ev, dint, nerr)

```

Version: aptrklc Updated 1990 March 14 16:00.
aptrklc Originated 1990 January 11 15:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read ,245100;aptslibe / 1 1
lib aptslibe|x aptblibe aptrklc|end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, any intersection point $e = (eu, ev)$ of the linear track through point $a = (au, av)$ with the direction vector $ab = (abu, abv)$, and the line segment from point $c = (cu, cv)$ to point $d = (du, dv)$, all in the uv plane of uvw space, for which (1) the distance from point "a" to point "e" is between the limits dintmn and dintmx, (2) point "e" is between point "c" and "d", and (3) the track crosses line "cd" from left to right in the uv plane. This is a zone exit if the points "c" and "d" are the vertices of a zone edge, counterclockwise around the zone in the uv plane. Flag nint indicates the type of intersection found. The distance dint of the intersection from point "a" is also returned. Flag nerr indicates any input error.

History: 1990 March 14. Changed tol to 0.0 in call to unit vector subroutine. Allows small magnitudes.

Input: au, av, abu, abv, cu, cv, du, dv, dintmn, dintmx, np, tol.

Output: nint, eu, ev, dint, nerr.

Calls: aptfdav, aptvadc, aptvaxc, aptydic, aptvubc
(sources in aptslibe, binaries in aptblibe).

Glossary:

au, av	Input	The u and v coordinates of point "a". Size np. In the uv plane.
abu, abv	Input	The u and v components of 2-D direction vector "ab". Must not both be zero. Size np.
cu, cv	Input	The u and v coordinates of point "c" in the uv plane. Must differ from "d", based on tol. Size np.
du, dv	Input	The u and v coordinates of point "d" in the uv plane. Must differ from "c", based on tol. Size np.
dint	Output	The distance of the point of intersection "e" from point "a". Positive if in the same direction as vector "ab". Size np.
dintmn	Input	Minimum allowed value of distance to intersection. Size np.
dintmx	Input	Maximum allowed value of distance to intersection. Size np.
eu, ev	Output	The u and v coordinates of the point of intersection of the line through point "a" with direction vector "ab", and line "cd", all in the uv plane.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
nint	Output	Number of acceptable intersections found. 0 if none. 1 if an acceptable intersection was found. 2 if the track coincides with part of line "cd".
np	Input	Size of arrays.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTRKPL

```

call aptrkpl (px, py, pz, vx, vy, vz, ax, ay, az,
             bx, by, bz, cx, cy, cz, np, tol,
             dpmn, dint, qx, qy, qz, ipar, nerr)

```

Version: aptrkpl Updated 1990 March 15 16:40.
aptrkpl Originated 1989 November 30 15:30.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptrkplend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUIID library of Cray-compiled binaries.

Purpose: To find, for each of np sets of input data, the point of intersection $q = (qx, qy, qz)$ of the linear track through point $p = (px, py, pz)$ with direction vector $v = (vx, vy, vz)$, and the plane through points $a = (ax, ay, az)$, $b = (bx, by, bz)$, and $c = (cx, cy, cz)$, and the distance dint between points "p" and "q". The perpendicular distance dpmn from the plane to point "p" is also returned.

If the vector "v" is parallel to the plane, flag ipar will be 1. If so, and dpmn is not zero, dint and the coordinates of point "q" will be very large. Otherwise, if dpmn is zero, dint will be zero, and the coordinates of point "q" will be those of point "p".

Flag nerr indicates any input error.

History: 1990 March 14. Changed tol to 0.0 in call to unit vector sub-routine. Allows small magnitudes.
1990 March 15. Changed the values of dpmn, dint, and point "q" when the plane "abc" is undefined (ipar = 3 or 4). No effect on problems with good input data.

Input: px, py, pz, vx, vy, vz, ax, ay, az, bx, by, bz, cx, cy, cz, tol.

Output: dpmn, dint, qx, qy, qz, ipar, nerr.

Calls: aptvadd, aptvdis, aptvdot, aptvpln, aptvuna, aptvunb
(sources in aptslibe, binaries in aptblibe).

Glossary:

ax,ay,az	Input	The x, y, z coordinates of point "a" in the plane. Must differ from "b" and "c", based on tol. Size np.
bx,by,bz	Input	The x, y, z coordinates of point "b" in the plane. Must differ from "a" and "c", based on tol. Size np.
cx,cy,cz	Input	The x, y, z coordinates of point "c" in the plane. Must differ from "a" and "b", based on tol. Size np.
dint	Output	The distance of the point of intersection "q" from point "p", if ipar = 0. Positive if in the same direction as vector "v". Size np. Meaningless, but large if ipar = 1. Meaningless, but zero if ipar = 2, 3, or 4.
dpmn	Output	The perpendicular distance to point "p" from the plane. Positive if point "p" is on the side of the plane for which points "a", "b", and "c" are counterclockwise. Meaningless if ipar = 2, 3, or 4. If less than the estimated error in its calculation, dpmn will be truncated to zero. Size np.
ipar	Output	0 if vector "v" is not parallel to the plane. Size np. 1 if it is. See dpmn, dint, qx, qy, qz. 2 if vector "v" is too short, based on tol. 3 if any of the points "a", "b", and "c" coincide. 4 if "v" is too short, and "a", "b" or "c" coincide.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays.

px,py,pz Input The x, y, z coordinates of point "p".

qx,qy,qz Output The x, y, z coordinates of the point of intersection of the line through point "p" with unit direction vector "v", and the plane through points "a", "b", and "c", if ipar = 0. Size np. Meaningless, but large if ipar = 1. Meaningless, but zero if ipar = 2, 3 or 4.

vx,vy,vz Input The x, y, z components of direction vector "v".

tol Input Numerical tolerance limit.
On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTKRL

call aptkrl (pr, ur, sr, dr, dintmn, dintmx, np, tol,
nint, dint, nerr)

Version: aptkrl Updated 1990 January 24 15:50.
aptkrl Originated 1990 January 19 16:20.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100;aptslibe / 1 1
lib aptslibe;x aptblibe aptkrlend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, any exit intersection of the linear track through point p = (pr) with unit direction vector u = (ur, ut, up), with the spherical surface with fixed radius sr, for which (1) the distance dint from point "p" to the intersection is between the limits dintmn and dintmx, and (2) the radial component ur of the direction vector "u" at the intersection has the same sign as dr. Flag nerr indicates any input error.

Input: pr, ur, sr, dr, dintmn, dintmx, np, tol.

Output: nint, dint, nerr.

Calls: aptqrv, aptvlim (aptdav optional)
(sources in aptslibe, binaries in aptblibe).

Glossary:

dint	Output	Distance from point "p" to intersection at radius sr along track (not radial distance).
dintmn	Input	Minimum allowed value of distance to intersection. Size np.
dintmx	Input	Maximum allowed value of distance to intersection. Size np.
dr	Input	Sign of exit direction through surface at sr. Size np.
nerr	Output	If not 0, indicates an input error. 1 if np is not positive.
nint	Output	0 if no exit intersection was found. 1 if an exit intersection was found at the surface at radius sr, with a distance to intersection dint between dintmn and dintmx. Size np.
np	Input	Size of arrays pr, ur, sr, dr, dintmn, dintmx, nint.
pr	Input	Spherical radial coordinate of initial point on track. Size np.
sr	Input	Spherical radial coordinate of surface. Size np.
ur	Input	Initial spherical radial component of unit direction vector along track. Size np.
tol	Input	Truncation error limit. Used to test for intersection being nearly tangent, and for accuracy of intersection. Must not be zero. On Cray computers, recommend 1.e-11.

SUBROUTINE APTRKSL

```
call aptrksl (au, abu, cu, du, dintmn, dintmx, np, tol,
             nint, cu, dint, nerr)
```

Version: aptrksl Updated 1990 January 24 16:00.
 aptrksl Originated 1990 January 11 15:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100;aptsliba / 1 1
 lib aptsliba|x aptblibe aptrksllend / 1 1.
 aptsliba is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, any intersection of the linear track through point a = (au) in the direction of the unit vector ab = (abu, abv, abw), with the vw plane through the point c = (cu), with the normal vector d = (du), for which (1) the distance dint from point "a" to the intersection is between the limits dintmn and dintmx, and (2) the direction vector abu has the same sign as du. This is equivalent to a zone exit in 1-D slab geometry, if du has the sign of the direction out of the zone at point cu. Flag nint indicates the type of intersection found. Flag nerr indicates any input error.

To find a zone exit in 1-D slab geometry.

Input: au, abu, cu, du, dintmn, dintmx, np, tol.

Output: nint, dint, nerr.

Calls: aptvdil (source in aptsliba, binary in aptblibe).

Glossary:

au	Input	The u coordinate of point "a". The v and w coordinates are zero. Directions u, v and w are orthogonal. Size np.
abu	Input	The u component of the unit direction vector "ab" along the track in uvw space. Size np. An acceptable intersection can only occur if abu has the same sign as du.
cu	Input	The u coordinate of point "c". Size np.
dint	Output	The distance of the point of intersection of the track from point "a" to the uv plane through point "c". Positive if in the same direction as vector "ab". Size np.
du	Input	The u component of the outward normal vector of the vw plane at point "c". Size np. An acceptable intersection can only occur if abu has the same sign as du.
dintmn	Input	Minimum allowed value of distance to intersection dint. Size np.
dintmx	Input	Maximum allowed value of distance to intersection dint. Size np.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
nint	Output	Number of acceptable intersections found. 0 if none. 1 if an acceptable intersection was found.
np	Input	Size of arrays.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTRNDS

call aptrnds (nopt, x, dx, nsig, np, tol, nerr)

Version: aptrnds Updated 1990 February 2 10:40.
aptrnds Originated 1990 February 2 10:40.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1.
lib aptslibe!x aptblibe aptrnds!end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUFD library of Cray-compiled binaries.

Purpose: To find, for each of np values of x, the new value of x after rounding off to the nearest multiple of dx in the first nsig significant figures (nopt = 0), or in the absolute value (nopt = 1).
Flag nerr indicates any input error.

Input: nopt, x, dx, nsig, np.

Output: x, nerr.

Glossary:

dx	Input	Precision of rounded result in significant figure nsig (nopt = 0), or in absolute value (nopt = 1). Must not be zero. Normally from 1.0 to 5.0. Size np.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 2 if nopt is not 0 or 1.
nopt	Input	Indicates type of rounding off to be done. 0 to round off to the nearest multiple of dx in the first nsig significant figures of x. 1 to round off to the nearest multiple of dx in the absolute value of x.
np	Input	Size of arrays x, dx, and if nopt = 0, nsig.
nsig	Input	Number of significant figures to be rounded off to the nearest multiple of dx (nopt = 0). Values less than 1 will be equivalent to 1. Values greater than the machine limit will have no effect. Size np, if nopt = 0. Otherwise, undimensioned.
tol	Input	Precision of mixed integer and floating point operations on machine. Recommend 1.e-11 on Cray.
x	In/Out	Value to be rounded off, and rounded result. Size np.

SUBROUTINE APTROTA

call aptrota (theta, ku, vx, vy, vz, tol, rotm, nerr)

Version: aptrota Updated 1989 March 14 16:00.
 aptrota Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe|x aptblibe aptrota!end / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the rotation matrix operator rotm, to do a
 counterclockwise rotation by the angle theta, around the
 axis parallel to the vector $v = (vx, vy, vz)$.
 (Counterclockwise: with the axis pointed at the observer.)
 The angle may be in degrees ($ku = 0$) or radians ($ku = 1$).
 Flag nerr indicates any error in v (too small) or ku (not 0, 1).

History: 1990 March 14. Changed tol to 0.0 in call to unit vector
 subroutine. Allows small magnitudes.

Input: theta, ku, vx, vy, vz.

Output: rotm, nerr.

Calls: aptvunb (source in aptslibe, binary in aptblibe).

Glossary:

ku	Input	Indicates theta units are degrees (0) or radians (1).
nerr	Output	Indicates an input error, if not 0. 1 if magnitude of (vx, vy, vz) too small. 2 if ku is not 0 or 1.
rotm	Output	Rotation operator (a unitary 3 x 3 matrix). Must be sized rotm(3,3).
theta	Input	Angle of rotation around axis, counterclockwise when rotation axis is pointed at observer. Units are degrees ($ku = 0$) or radians ($ku = 1$).
tol	Input	Numerical tolerance limit. Used to test and adjust unit vector components and point coordinates. On Cray computers, recommend 1.e-5 to 1.e-11.
vx	Input	The x component of vector parallel to rotation axis.
vy	Input	The y component of vector parallel to rotation axis.
vz	Input	The z component of vector parallel to rotation axis.

SUBROUTINE APTROT C

call aptrotc (au, av, bu, bv, cu, cv, np, tol, nerr)

Version: aptrotc Updated 1990 March 14 16:00.
aptrotc Originated 1989 December 29 10:00.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibelx aptblibe aptrotclend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To rotate the np 2-D vectors $c = (cu, cv)$ around the w axis by the angle needed to make 2-D vector $a = (au, av)$ parallel to 2-D vector $b = (bu, bv)$. All are in the uv plane. Directions u, v and w are orthogonal. Any new components of $c = (cu, cv)$ that are smaller than their estimated error, based on tol, will be truncated to zero. Flag nerr indicates any input error.

History: 1990 March 14. Changed tol to 0.0 in call to unit vector subroutine. Allows small magnitudes.

Input: au, av, bu, bv, cu, cv, tol.

Output: cu, cv, nerr.

Calls: aptvaxc, aptvdoc, aptvubc (sources in aptslibe,
binaries in aptblibe).

Glossary:

au, av	Input	The u and v components of the first vector. The w components are zero.
bu, bv	Input	The u and v components of the second vector. The w components are zero.
cu, cv	Input	The u and v components of vector "c". Size np. The w components are zero.
cu, cv	Output	The u and v components of vector "c", after rotation. The w components are zero. Will be truncated to zero, if smaller than the estimated error in their calculation, based on tol. Size np.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 2 if vector "a" is too short. 3 if vector "b" is too short.
np	Input	The size of arrays cu, cv.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTROTP

call aptrotp (ax, ay, az, bx, by, bz, cx, cy, cz,
& dx, dy, dz, tol, rotm, nerr)

Version: aptrotp Updated 1989 March 14 16:00.
aptrotp Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptrotp|end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the rotation matrix operator rotm, for rotating the plane containing the vectors a = (ax, ay, az) and b = (bx, by, bz) to be parallel to the plane containing the vectors c = (cx, cy, cz) and d = (dx, dy, dz), around an axis parallel to both planes. Any components of rotm within tol of -1.0, 0.0, or 1.0, will be truncated to those values. Flag nerr indicates any input error.

History: 1990 March 14. Changed tol to 0.0 in call to unit vector subroutine. Allows small magnitudes.

Input: ax, ay, az, bx, by, bz, cx, cy, cz, dx, dy, dz.

Output: rotm, nerr.

Calls: aptvaxb, aptvuna, aptvxun (sources in aptslibe, binaries in aptblibe).

Glossary:

ax,ay,az	Input	The x, y, z components of a vector.
bx,by,bz	Input	The x, y, z components of a vector.
cx,cy,cz	Input	The x, y, z components of a vector.
dx,dy,dz	Input	The x, y, z components of a vector.
nerr	Output	Indicates an input error, if not 0. 1 if the magnitude of any input vector is too small, or the two vectors in a plane are almost parallel.
rotm	Output	Rotation operator (a unitary 3 x 3 matrix). Must be sized rotm(3,3).
tol	Input	Numerical tolerance limit. Used to test and adjust unit vector components and point coordinates. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTROTS

```
call aptrots (n1, th1, n2, th2, n3, th3, ku, tol,  
rotm, nerr)
```

Version: aptrots Updated 1989 November 13 15:20.
aptrots Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptrots|end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the rotation matrix operator rotm, to do a sequential rotation of angle th1 around axis n1, angle th2 around axis n2, and angle th3 around axis n3. All angles are measured counterclockwise, with the axis pointed at the observer. The axes may be x (1), y (2), or z (3). Angles may be in degrees (ku = 0) or radians (ku = 1). Flag nerr indicates any input error.

Input: n1, th1, n2, th2, n3, th3, ku, tol.

Output: rotm, nerr.

Glossary:

ku	Input	Indicates theta units are degrees (0) or radians (1).
n1	Input	Indicates first axis is x (1), y (2), or z (3). May not be 0, but th1 may be 0.
n2	Input	Indicates second axis is x (1), y (2), or z (3). May not be 0, but th2 may be 0.
n3	Input	Indicates third axis is x (1), y (2), or z (3). May not be 0, but th3 may be 0.
nerr	Output	Indicates an input error, if not 0. 1 if n1, n2, or n3 not in range 1-3, or not unique. 2 if ku is not 0 or 1.
rotm	Output	Rotation operator (a unitary 3 x 3 matrix). Must be sized rotm(3,3).
th1	Input	Angle of rotation around axis n1, counterclockwise when rotation axis is pointed at observer. Units are degrees (ku = 0) or radians (ku = 1).
th2	Input	Angle of rotation around axis n2. See th1.
th3	Input	Angle of rotation around axis n3. See th1.
tol	Input	Numerical tolerance limit. Used to test and adjust unit vector components and point coordinates. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTROTT

call aptrott (ax, ay, az, bx, by, bz, cx, cy, cz,
dx, dy, dz, tol, rotm, nerr)

Version: aptrott Updated 1990 March 14 16:00.
aptrott Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, I-298, Telephone (415) 422-4123.

Source: xport read 245/00:aptslibe / 1 1
lib aptvlibe aptblibe aptrottlend / 1 1.
aptslibe is a /IB library of FORTRAN source files.
apblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the rotation matrix operator rotm, for rotating the vector $a = (ax, ay, az)$ and the plane containing vectors "a" and $b = (bx, by, bz)$, to be parallel to vector $c = (cx, cy, cz)$ and the plane containing vectors "c" and $d = (dx, dy, dz)$. Any components of rotm within tol of -1.0, 0.0, or 1.0, will be truncated to those values. Flag nerr indicates any input error.

If vectors "a" and "b" are the first two vectors of the positive vector triple (a, b, a x b), and c and d are the first two vectors of the positive vector triple (c, d, c x d), then rotm rotates (a, b, a x b) onto (c, d, c x d), or equivalently, redefines the coordinate axes to be (a, b, c x d) instead of (c, d, c x d). (a x b indicates the vector product of a and b.)

History: 1990 March 14. Changed tol to 0.0 in call to unit vector subroutine. Allows small magnitudes.

Input: ax, ay, az, bx, by, bz, cx, cy, cz, dx, dy, dz, tol.

Output: rotm, nerr.

Calls: aptvxun, aptvunb (sources in aptslibe,
binaries in aptblibe).

Glossary:

ax,ay,az	Input	The x, y, z components of a vector.
bx,by,bz	Input	The x, y, z components of a vector.
cx,cy,cz	Input	The x, y, z components of a vector.
dx,dy,dz	Input	The x, y, z components of a vector.
nerr	Output	Indicates an input error, if not 0. 1 if the magnitude of any input vector is too small, or the two vectors in a plane are almost parallel.
rotm	Output	Rotation operator (a unitary 3 x 3 matrix). Must be sized rotm(3,3).
tol	Input	Numerical tolerance limit. Used to test and adjust unit vector components and point coordinates. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTROTV

call aptrotv (ax, ay, az, bx, by, bz, tol, rotm, nerr)

Version: aptrotv Updated 1990 March 14 16:00.
aprotv Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptrotv|end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the rotation matrix operator "rotm", for rotating
the vector a = (ax, ay, az) to be parallel to the vector
b = (bx, by, bz), around an axis perpendicular to both.
Any components of "rotm" within tol of -1.0, 0.0, or 1.0,
will be truncated to those values.
Flag nerr indicates any input error.

History: 1990 March 14. Changed tol to 0.0 in call to unit vector
subroutine. Allows small magnitudes.

Input: ax, ay, az, bx, by, bz, tol.

Output: rotm, nerr.

Calls: aptvxun, aptvdot, aptvunb (sources in aptslibe,
binaries in aptblibe).

Glossary:

ax,ay,az	Input	The x, y, z components of vector "a".
bx,by,bz	Input	The x, y, z components of vector "b".
nerr	Output	Indicates an input error, if not 0. 1 if the magnitude of vector "a" or "b" is too small.
rotm	Output	Rotation operator (a unitary 3 x 3 matrix). Must be sized rotm(3,3).
tol	Input	Numerical tolerance limit. Used to test and adjust unit vector components and point coordinates. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTSCAD

call aptscad (np, au, av, aw, bu, bv, bw, nerr)

Version: aptscad Updated 1990 February 27 10:20.
aptscad Originated 1990 February 27 10:20.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptscad|end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find np unit vectors $b = (bu, bv, bw)$, representing random directions uniformly distributed in a plane with the normal vector $a = (au, av, aw)$ in 3-D space. Flag nerr indicates any input error (np not positive).

Calls: aptscat, aptvxun
(sources in aptslibe, binaries in aptblibe).

Input: np, au, av, aw.

Output: bu, bv, bw, nerr.

Glossary:

au,av,aw Input The u, v and w components of the vector normal to the plane in which the vectors "b" are to be.

bu Output The u component of a unit vector representing a direction chosen randomly from a uniform distribution in 3-D space, in the plane with normal vector "a". Coordinates u, v and w may be any 3 orthogonal coordinates. Size np.

bv Output The v component of a unit vector representing a direction chosen randomly from a uniform distribution in 3-D space, in the plane with normal vector "a". Coordinates u, v and w may be any 3 orthogonal coordinates. Size np.

bw Output The w component of a unit vector representing a direction chosen randomly from a uniform distribution in 3-D space, in the plane with normal vector "a". Coordinates u, v and w may be any 3 orthogonal coordinates. Size np.

nerr Output Indicates an input error, if not 0.
1 if np is not positive.

np Input Size of arrays.

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SUBROUTINE APTSCAP

call aptscap (np, au, av, aw, pm,
bu, bv, bw, nerr)

Version: aptscap Updated 1990 January 10 10:30.
aptscap Originated 1990 January 10 10:30.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptscaplend /'1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find np unit vectors $b = (bu, bv, bw)$, representing random directions in a cosine**pm distribution in 3-D space, centered on an axis in the direction of vector $a = (au, av, aw)$, with the restrictions that the magnitudes of the components be no smaller than the specified limits tolu, tolv, tolw, respectively. Flag nerr indicates any input error.

If "ba" is the expected value of the component of vector "b" in the direction of vector "a", then:

$ba = (pm + 1.0) / (pm + 2.0)$. (ba .ge. 0.5).
 $pm = (2.0 * ba - 1.0) / (1.0 - ba)$. (pm .ge. 0.0).
pm = 0.0: isotropic in half-space.
pm = 1.0: cosine distribution in half-space.

Calls: aptmopv, aptrotv, aptvlim
(sources in aptslibe, binaries in aptblibe).

Input: np, tolu, tolv, tolw, au, av, aw, pm.

Output: bu, bv, bw, nerr.

Glossary:

au,av,aw	Input	The u, v and w components of a vector in the direction of the center of a cosine**pm distribution.
bu	Output	The u component of a unit vector representing a direction chosen randomly from a cosine**pm distribution in 3-D space, centered in the direction of vector "a". Coordinates u, v and w may be any 3 orthogonal coordinates. Size np. Magnitude may be no smaller than tolu.
bv	Output	The v component of a unit vector representing a direction chosen randomly from a cosine**pm distribution in 3-D space, centered in the direction of vector "a". Coordinates u, v and w may be any 3 orthogonal coordinates. Size np. Magnitude may be no smaller than tolv.
bw	Output	The w component of a unit vector representing a direction chosen randomly from a cosine**pm distribution in 3-D space, centered in the direction of vector "a". Coordinates u, v and w may be any 3 orthogonal coordinates. Size np. Magnitude may be no smaller than tolw.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays.
pm	Input	Power used for the cosine**pm spatial distribution from which unit vector "b" is to be chosen.
tolu	Input	Minimum magnitude of all bu components. On Cray computers, recommend 1.e-5.
tolv	Input	Minimum magnitude of all bv components. On Cray computers, recommend 1.e-5.
tolw	Input	Minimum magnitude of all bw components. On Cray computers, recommend 1.e-5.

SUBROUTINE APTSCAT

call aptscat (np, au, av, aw, nerr)

Version: aptscat Updated 1990 January 10 10:40.
aptscat Originated 1990 January 10 10:40.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibelx aptblibe aptscatlend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find np unit vectors $a = (au, av, aw)$, representing random directions in 3-D space, with the restrictions that the magnitudes of the components be no smaller than the specified limits tolu, tolv, tolw, respectively. Flag nerr indicates any input error (np not positive).

Input: np, tolu, tolv, tolw.

Output: au, av, aw, nerr.

Calls: aptvlim (source in aptslibe, binary in aptblibe).

Glossary:

au	Output	The u component of a unit vector representing a random direction in 3-d space. Coordinates u, v and w may be any 3 orthogonal coordinates. Size np. Magnitude may be no smaller than tolu.
av	Output	The v component of a unit vector representing a random direction in 3-d space. Coordinates u, v and w may be any 3 orthogonal coordinates. Size np. Magnitude may be no smaller than tolv.
aw	Output	The w component of a unit vector representing a random direction in 3-d space. Coordinates u, v and w may be any 3 orthogonal coordinates. Size np. Magnitude may be no smaller than tolw.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays.
tolu	Input	Minimum magnitude of all au components. On Cray computers, recommend 1.e-5.
tolv	Input	Minimum magnitude of all av components. On Cray computers, recommend 1.e-5.
tolw	Input	Minimum magnitude of all aw components. On Cray computers, recommend 1.e-5.

SUBROUTINE APTSCLC

call aptsclc (scale, au, av, bu, bv, pu, pv, np, tol, nerr)

Version: aptsclc Updated 1990 March 14 16:00.
 aptsclc Originated 1990 January 4 15:00.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe|x aptblibe aptsclc|end / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To linearly scale the np points or vectors
 $p = (pu, pv)$ by the factor "scale", in the direction of the
 vector $a = (au, av)$, with the point $b = (bu, bv)$ invariant.
 All are in the uv plane. If $p = (pu, pv)$ are unbound vectors,
 invariant point "b" must be at the origin.
 This is the spatial part of a Lorentz transformation.
 Flag nerr indicates any input error.

History: 1990 March 14. Changed tol to 0.0 in call to unit vector
 subroutine. Allows small magnitudes.

Input: scale, au, av, bu, bv, pu, pv, np, tol.

Output: pu, pv, nerr.

Calls: aptvubc (source in aptslibe, binary in aptblibe).

Glossary:

au, av	Input	The u and v components of the uv plane vector defining the direction of linear scaling.
bu, bv	Input	The u, v coordinates of the uv plane invariant point.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 2 if the magnitude of vector "a" is too small, relative to tol.
np	Input	Size of arrays pu, pv.
pu, pv	In/Out	The u and v coordinates of a point, or components of a vector in the uv plane. Size np.
tol	Input	Numerical tolerance limit. Used to test and adjust unit vector, matrix element, and point components. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTSCLL

call aptscll (scale, ax, ay, az, bx, by, bz, px, py, pz, np,
tol, refm, nerr)

Version: aptscll Updated 1990 March 14 16:00.
 aptscll Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read ,245100:aptslibe / 1 1
 lib aptslibe|x aptblibe aptscllend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the matrix operator refm for linear scaling with the
factor scale, in the direction of the vector $a = (ax, ay, az)$,
with the point $b = (bx, by, bz)$ invariant, and to do the
scaling on the np points or vectors $p = (px, py, pz)$.
np may be 0. If $p = (px, py, pz)$ are unbound vectors, make
sure invariant point "b" is at the origin.
This is the spatial part of a Lorentz transformation.
Any components of refm within tol of -1.0, 0.0, or 1.0,
will be truncated to those values.
flag nerr indicates any input error.

History: 1990 March 14. Changed tol to 0.0 in call to unit vector
subroutine. Allows small magnitudes.

Input: scale, ax, ay, az, bx, by, bz, px, py, pz, np, tol.

Output: px, py, pz, refm, nerr.

Calls: aptvunb, aptmpv (sources in aptslibe, binaries in aptblibe).

Glossary:

ax,ay,az	Input	The x, y, z components of vector "a" in the direction of linear scaling.
bx,by,bz	Input	The x, y, z coordinates of invariant point "b".
nerr	Output	Indicates an input error, if not 0. 1 if the magnitude of vector "a" is too small, relative to tol.
np	Input	Number of points or vectors "p". May be 0.
px,py,pz	In/Out	The x, y, z coordinates or components of point or vector "p", before and after scaling. Size np.
refm	Output	Linear scaling operator (a unitary 3 x 3 matrix). Must be sized refm(3,3).
scale	Input	Linear scaling factor. A negative value is equivalent to a positive linear scaling, followed by a reflection in the plane with the normal vector "a".
tol	Input	Numerical tolerance limit. Used to test and adjust unit vector, matrix element, and point components. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTSCLU

call aptsclu (scale, bx, by, bz, px, py, pz, np, tol,
4 refm, nerr)

Version: aptsclu Updated 1990 March 13 16:00.
aptsclu Originated 1990 March 13 16:00.

Author: Arthur L. Edwards, LLNL, L-296, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptsclulend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the matrix operator refm for uniform scaling by the factor "scale", with the point b = (bx, by, bz) invariant, and to do the scaling on the np points or vectors p = (px, py, pz). The array size np may be 0. If "p" are unbound vectors, invariant point "b" must be at the origin. Flag nerr indicates any input error.

Input: scale, bx, by, bz, px, py, pz, np, tol.

Output: px, py, pz, refm, nerr.

Calls: aptvunb, aptmopv (sources in aptslibe, binaries in aptblibe).

Glossary:

bx,by,bz	Input	The x, y, z coordinates of invariant point "b".
nerr	Output	Indicates an input error, if not 0. 1 if scale = 0.0.
np	Input	Number of points or vectors "p". May be 0.
px,py,pz	In/Out	The x, y, z coordinates or components of point or vector "p", before and after scaling. Size np.
refm	Output	Linear scaling operator (a unitary 3 x 3 matrix). Must be sized refm(3,3).
scale	Input	Scale factor for uniform scaling. A negative value is equivalent to a positive scaling, followed by an inversion. A value of 0.0 is treated as an error.
tol	Input	Numerical tolerance limit. Used to test and adjust unit vector, matrix element, and point components. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTSLID

call aptslid (xa, pa, xb, pb, np, xran, nerr)

Version: aptslid Updated 1990 February 7 14:00.
 aptslid Originated 1990 February 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read ,245100;aptslibe / 1 1
 lib aptslibe|x aptblibe aptslid|end / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find np values of x, by sampling from a linear distribution function having probability pa at xa, and probability pb at xb. Flag nerr indicates any input error.

If both pa and pb are non-negative, the expected value of x is
 $\langle x \rangle = fa * xa + fb * xb$,
 where $fa = (2.0 * pa + pb) / (3.0 * (pa + pb))$
 and $fb = (pa + 2.0 * pb) / (3.0 * (pa + pb))$.

If pa is negative, and pb is positive, then nerr = 3,
 no values of x will be sampled between xa and
 $xa' = (xa * pb - xb * pa) / (pb - pa)$, and
 $\langle x \rangle = fa' * xa + fb' * xb$,
 where $fa' = pb / (3.0 * (pb - pa))$
 and $fb' = (2.0 * pb - 3.0 * pa) / (3.0 * (pb - pa))$.

If pa is positive, and pb is negative, then nerr = 3,
 no values of x will be sampled between xb and
 $xb' = (xb * pa - xa * pb) / (pa - pb)$, and
 $\langle x \rangle = fa' * xa + fb' * xb$,
 where $fa' = (2.0 * pa - 3.0 * pb) / (3.0 * (pa - pb))$
 and $fb' = pa / (3.0 * (pa - pb))$.

If both pa and pb are non-positive, then nerr = 2, and
 no values of x will be sampled.

History: 1990 February 5 13:20. Modified to eliminate sampling from any range of x with negative probability.

Input: xa, pa, xb, pb, np.

Output: xran, nerr.

Glossary:

nerr Output Indicates an input error, if not 0.
 1 if np is not positive.
 2 if both pa and pb are non-positive.
 No x values are sampled.
 3 if either pa or pb is negative, and the other is positive. Values of x are sampled only from the positive part of the probability distribution.

np Input Size of array xran.

pa, pb Input Relative probabilities of random variables xa and xb, respectively. Probability p(x) is linear in x. The values of pa and pb need not be normalized. If neither pa nor pb is positive (nerr = 2), no values of x will be sampled. If either pa or pb is negative, and the other is positive, (nerr = 3), x values will only be sampled from the positive part of the probability distribution.
 To find pa and pb, when $\langle x \rangle$ is given:
 $xma = (2.0 * xa + xb) / 3.0$,
 $xmb = (xa + 2.0 * xb) / 3.0$.
 For $\langle x \rangle$ between xa and xma, pb is negative, and:
 $pb = -((xma - \langle x \rangle) / (\langle x \rangle - xa)) * pa$.
 For $\langle x \rangle$ between xma and xmb:
 $(\langle x \rangle - xma) * pa = (xmb - \langle x \rangle) * pb$.
 For $\langle x \rangle$ between xmb and xb, pa is negative, and:
 $pa = -((\langle x \rangle - xmb) / (xb - \langle x \rangle)) * pb$.

xa, xb Input Values of random variable x with relative probabilities pa and pb, respectively.

xran Output Randomly sampled value of x in range from xa to xb. Size np.

SUBROUTINE APTSLIV

call aptsliv (xa, pa, xb, pb, np, xran, nerr)

Version: aptsliv Updated 1990 February 7 14:00.
 aptsliv Originated 1990 February 6 11:40.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100;aptslibe / 1 1
 lib aptslibe!x aptblibe aptsliv!end / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find np values of x, by sampling from np linear probability
 distribution functions having probabilities pa at xa, and
 probabilities pb at xb.
 Flag nerr indicates any input error.

If both pa and pb are non-negative, the expected value of x is
 $\langle x \rangle = fa * xa + fb * xb$,
 where $fa = (2.0 * pa + pb) / (3.0 * (pa + pb))$
 and $fb = (pa + 2.0 * pb) / (3.0 * (pa + pb))$.

If pa is negative, and pb is positive, then
 no values of x will be sampled between xa and
 $xa' = (xa * pb - xb * pa) / (pb - pa)$, and
 $\langle x \rangle = fa' * xa + fb' * xb$,
 where $fa' = pb / (3.0 * (pb - pa))$
 and $fb' = (2.0 * pb - 3.0 * pa) / (3.0 * (pb - pa))$.

If pa is positive, and pb is negative, then
 no values of x will be sampled between xb and
 $xb' = (xb * pa - xa * pb) / (pa - pb)$, and
 $\langle x \rangle = fa' * xa + fb' * xb$,
 where $fa' = (2.0 * pa - 3.0 * pb) / (3.0 * (pa - pb))$
 and $fb' = pa / (3.0 * (pa - pb))$.

If both pa and pb are non-positive, then the returned value
 will be -1.e99.

Input: xa, pa, xb, pb, np.

Output: xran, nerr.

Glossary:

nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays xa, pa, xb, pb, xran.
pa, pb	Input	Relative probabilities of random variables xa and xb, respectively. Probability p(x) is linear in x. The values of pa and pb need not be normalized. A value of x will be sampled only from the positive range of each probability distribution function. If neither pa nor pb is positive, the value of xran will be -1.e99. Size np. To find pa and pb, when $\langle x \rangle$ is given: $xma = (2.0 * xa + xb) / 3.0$, $xmb = (xa + 2.0 * xb) / 3.0$. For $\langle x \rangle$ between xa and xma, pb is negative, and: $pb = -((xma - \langle x \rangle) / (\langle x \rangle - xa)) * pa$. For $\langle x \rangle$ between xma and xmb: $(\langle x \rangle - xma) * pa = (xmb - \langle x \rangle) * pb$. For $\langle x \rangle$ between xmb and xb, pa is negative, and: $pa = -((\langle x \rangle - xmb) / (xb - \langle x \rangle)) * pb$.
xa, xb	Input	Values of random variable x with relative probabilities pa and pb, respectively. Size np.
xran	Output	Randomly sampled value of x in range from xa to xb. Value returned is -1.e99 if neither pa nor pb is positive. Size np.

SUBROUTINE APTSPSP

```
call aptspsp (ra, ax, ay, az, rb, bx, by, bz, np, tol,  
6          rc, cx, cy, cz, abx, aby, abz, nerr)
```

Version: aptspsp Updated 1990 March 20 14:00.
aptspsp Originated 1990 March 20 14:00.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe!x aptblibe aptspsp!end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of np sets of input data, the radius rc and center c = (cx, cy, cz) of the circle of intersection of the sphere of radius ra at point a = (ax, ay, az) and the sphere of radius rb at point b = (bx, by, bz), if an intersection occurs. Vector ab = (abx, aby, abz) is normal to the plane of the circle. Flag nerr indicates any input error.

Input: ra, ax, ay, az, rb, bx, by, bz, np, tol.

Output: rc, cx, cy, cz, abx, aby, abz, nerr.

Calls: aptvdis, aptvadd, aptvuna (sources in aptslibe,
binaries in aptblibe).

Glossary:

abx,y,z	Output	The x, y, z components of the unit vector "ab", normal to any plane containing any circle of intersection of the two spheres. In the direction from point "a" to point "b". Zero if points "a" and "b" coincide, within the limit of precision tol.
ax,ay,az	Input	The x, y, z coordinates of point "a" at the center of the sphere with radius ra. Size np.
bx,by,bz	Input	The x, y, z coordinates of point "b" at the center of the sphere with radius rb. Size np.
cx,cy,cz	Output	The x, y, z coordinates of point "c" at the center of the circle with radius rc, at the intersection of the two spheres, if an intersection occurs.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays.
ra	Input	The radius of the sphere centered at point "a". Size np. Absolute value will be used.
rb	Input	The radius of the sphere centered at point "b". Size np. Absolute value will be used.
rc	Output	The radius of the circle centered at point "c", at the intersection of the two spheres, if an intersection occurs. Size np. Positive if the spheres intersect. Zero if the spheres are tangent. Negative if the spheres do not intersect.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTTINC

```
call apttinc (au, av, bu, bv, cu, cv, pu, pv, np, tol,
&            pab, pbc, pca, dpmin, nloc, nerr)
```

Version: apttinc Updated 1990 February 21 15:20.
 apttinc Originated 1990 February 21 15:20.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe!x aptblibe apttinc!end / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, the distances pab, pbc and pca from the point p = (pu, pv) to the sides of the triangle with vertices a = (au, av), b = (bu, bv) and c = (cu, cv), in counterclockwise order in the uv plane, the minimum dpmin of the distances pab, pbc and pca, and whether point "p" is inside the triangle or not (flag nloc). The values of pab, pbc and pca will be truncated to zero, if less than the estimated error in their calculation, based on tol. Flag nerr indicates any input error.

Input: au, av, bu, bv, cu, cv, pu, pv, np, tol.

Output: pab, pbc, pca, dpmin, nloc, nerr,

Calls: apttinc (source in aptslibe, binary in aptblibe).

Glossary:

au, av	Input	The u, v coordinates of vertex "a" of the triangle. Size np.
bu, bv	Input	The u, v coordinates of vertex "b" of the triangle. Size np.
cu, cv	Input	The u, v coordinates of vertex "c" of the triangle. Size np.
dpmin	output	The minimum of the distances pab, pbc and pca. Size np.
nloc	Output	Indicates the location of point "p" relative to the triangle "abc": -1 if all triangle vertices coincide. 0 if point "p" is outside the triangle "abc" (one or two of pab, pbc, pca are negative), or is inside, but the triangle vertices were specified in clockwise order (pab, pbc and pca are all non-positive). 1 if point "p" is inside triangle "abc" (pab, pbc and pbc are all non-negative).
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays pu, pv, au, av, bu, bv, cu, cv, pab, pbc, pca.
pab	Output	Distance from point "p" to triangle side "ab". Truncated to zero, if less than the estimated error in its calculation, based on tol.
pbc	Output	Distance from point "p" to triangle side "bc". Truncated to zero, if less than the estimated error in its calculation, based on tol.
pca	Output	Distance from point "p" to triangle side "ca". Truncated to zero, if less than the estimated error in its calculation, based on tol.
pu, pv	Input	The u and v coordinates of point "p" in the uv plane. Size np.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTTLOC

```
call apttloc (au, av, bu, bv, cu, cv, np, tol,
&            fdk, fdl, pu, pv, nerr)
```

Version: apttloc Updated 1990 February 8 14:30.
 apttloc Originated 1990 February 8 14:30.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe!x aptblibe apttlocend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find np points $p = (pu, pv)$, by sampling from a uniform distribution over the triangle in the uv plane with vertices $a = (au, av)$, $b = (bu, bv)$, $c = (cu, cv)$, in any order around the triangle.

Variables fdk and fdl are the local coordinates in the triangle. For any point $p = (pu, pv)$ in the triangle:

$$\begin{aligned} pu &= au + fdk * (bu - au) + fdl * (cu - bu) \\ pv &= av + fdk * (bv - av) + fdl * (cv - bv) \end{aligned}$$

$$\begin{aligned} fdk &= ((p - a) \times (c - b)) / ((b - a) \times (c - b)) \\ fdl &= -((p - a) \times (b - a)) / ((p - a) \times (c - b)), \end{aligned}$$

where a, b, c and p are the position vectors, \times indicates the vector product, and the scalar w components are used.

The unnormalized probability distribution for fdk and fdl is:

$$\text{prob}(fdk, fdl) = fdk$$

which is linear for fdk, uniform for fdl.

Flag nerr indicates any input error.

Input: au, av, bu, bv, cu, cv, np, tol.

Output: fdk, fdl, pu, pv, nerr.

Calls: aptslibe (source in aptslibe, binary in aptblibe).

Glossary:

au, av	Input	The u and v coordinates of vertex "a" of triangle.
bu, bv	Input	The u and v coordinates of vertex "b" of triangle.
cu, cv	Input	The u and v coordinates of vertex "c" of triangle.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays fdk, fdl, pu, pv. Number of points "p" to sample.
fdk	Output	Fractional distance of p int "p" between vertex "a" and side "bc". Range 0.0 to 1.0. Size np.
fdl	Output	Fractional distance of point "p" between the triangle sides "ab" and "ca". Range 0.0 to 1.0. Size np.
pu, pv	Output	Sampled point p. Size np.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APATTRAC

call apATTRAC (au, av, pu, pv, np, tol, nerr)

Version: apATTRAC Updated 1990 March 13 11:30.
apATTRAC Originated 1990 January 4 12:00.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe!x aptblibe apATTRAC!end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To translate the origin to the 2-D point $a = (au, av)$,
by subtracting the vector "a" from the np 2-D points
 $p = (pu, pv)$. New coordinates less than the estimated error
in their calculation, based on tol , will be truncated to zero.
Flag $nerr$ indicates any input error.

Input: au, av, pu, pv, np, tol.

Output: pu, pv, nerr.

Glossary:

nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 2 if the magnitude of (au, av) is no greater than tol .
np	Input	Number of 2-D points (pu, pv) .
tol	Input	Numerical tolerance limit. On Cray computers, recommend $1.e-5$ to $1.e-11$.
pu, pv	In/Out	The u and v coordinates of 2-D point "p". Size np . Truncated to zero if smaller than the estimated error in their calculation, based on tol .

SUBROUTINE APTTRAN

call apttran (ax, ay, az, px, py, pz, np, tol, nerr)

Version: apttran Updated 1990 March 13 11:30.
apttran Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe!x aptblibe apttran!end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To translate the origin to the point $a = (ax, ay, az)$,
by subtracting the vector "a" from the np points
 $p = (px, py, pz)$. New coordinates less than the estimated error
in their calculation, based on tol, will be truncated to zero.
Flag nerr indicates any input error.

Input: ax, ay, az, px, py, pz, np, tol.

Output: px, py, pz, nerr.

Glossary:

nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 2 if the magnitude of (ax, ay, az) is no greater than tol.
np	Input	Number of points (px, py, pz).
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.
px,py,pz	In/Out	The x, y, z coordinates of point "p". Size np. Truncated to zero if smaller than the estimated error in their calculation, based on tol.

+
SUBROUTINE APTTRIP

```
call apttrip (px, py, pz, ax, ay, az, bx, by, bz,  
4          cx, cy, cz, noptfd, tol,  
4          dpmin, fda, fdb, fdc, xmin, ymin, zmin,  
4          nlima, nlimb, nlimc, itrunc, nside, nerr)
```

Version: apttrip Updated 1990 January 18 14:20.
apttrip Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe apttriplend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the distance dpmin from a point p = (px, py, pz)
to a plane defined by the three points a = (ax, ay, az),
b = (bx, by, bz), and c = (cx, cy, cz), and the point
rmin = (xmin, ymin, zmin) nearest to point p, and in the plane,
subject to constraints that may be imposed by option noptfd
and the value of tol.

Optionally, to find the fractional distances (fda, fdb, fdc)
of point rmin along the triangle's altitudes.
Flags nlima, nlimb, nlimc indicate when fda, fdb, fdc have been
restrained. Flag itrunc indicates when dpmin has been truncated
to zero. Flag nside indicates when the minimum point is inside
the triangle. Flag nerr indicates any input error.

Input: ax, ay, az, bx, by, bz, cx, cy, cz, px, py, pz, tol.

Output: dpmin, fda, fdb, fdc, xmin, ymin, zmin,
nlima, nlimb, nlimc, itrunc, nside, nerr.

Calls: aptfdad, aptptin, aptvdis, aptvpln (sources in aptslibe,
binaries in aptblibe).

Glossary:

ax,ay,az	Input	The x, y, z coordinates of point "a".
bx,by,bz	Input	The x, y, z coordinates of point "b".
cx,cy,cz	Input	The x, y, z coordinates of point "c".
dpmin	Output	Distance from point "p" to the nearest (constrained) point in the plane defined by points "a", "b", "c". a value less than the estimated error in its calculation is truncated to zero (itrunc = 1). dpmin is positive when the external point is on the side of the plane for which the three points are in counterclockwise order. See noptfd.
fda	Output	Fractional distance of point (xmin, ymin, zmin) from side "bc" to vertex "a".
fdb	Output	Fractional distance of point (xmin, ymin, zmin) from side "ca" to vertex "b".
fdc	Output	Fractional distance of point (xmin, ymin, zmin) from side "ab" to vertex "c".
itrunc	Output	0 if no change is made in the calculated value of dpmin, 1 if dpmin is changed to zero, when less than the estimated error in its calculation.
nerr	Output	Indicates an input error, if not 0. 1 is added if noptfd is not between 0 and 2. 2 is added if 3 points representing triangle are collinear or congruent.
nlima	Output	0 if no limit imposed on fda, 1 if the limit of noptfd = 1 is imposed, 2 if the limit of noptfd = 2 is imposed.
nlimb,c	Output	Like nlima, but for fdb, fdc, respectively.

noptfd	Input	Option to limit range of fda, fdb, fdc: -1 for no limit, no calculation of fda, fdb, fdc, 0 for no limit, 1 to increase to tol, if in the range from -tol to tol, and decrease to 1.0 - tol, if in the range from 1.0 - tol to 1.0 + tol (move a point near an edge slightly inside the triangle), and 2 to limit to the range from 0.0 to 1.0 (move a point outside the triangle to an edge).
nside	Output	0 if minimum point outside the triangle, 1 if inside. 0 if moved to edge, when noptfd = 2.
px,py,pz	Input	The x, y, z coordinates of point "p".
tol	Input	Numerical tolerance limit for dpmin, fda, fdb, fdc. On Cray computers, recommend 1.e-5 to 1.e-11.
xmin	Output	The x coordinate of pt in plane nearest point "p". May be constrained by option noptfd.
ymin	Output	The y coordinate of pt in plane nearest point "p". May be constrained by option noptfd.
zmin	Output	The z coordinate of pt in plane nearest point "p". May be constrained by option noptfd.

SUBROUTINE APTVADC

```
call aptvadc (au, av, bmult, b, cu, cv, np, tol,
             du, dv, vlen, nerr)
```

Version: aptvadc Updated 1990 February 22 9:30.
 aptvadc Originated 1989 November 20 13:20.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe|x aptblibe aptvadclend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, the 2-D vector
 $\text{sum } d(n) = a(n) + \text{bmult} * b(n) * c(n)$, where $d = (du, dv)$,
 $a = (au, av)$, and $c = (cu, cv)$, and to find vlen, the
 magnitude of vector "d", all in the uv plane..
 Any component of vector "d" less than the estimated error in
 its calculation, based on tol, will be truncated to zero.
 Flag nerr indicates any input error.

History: 1990 February 22. Deleted truncation of vector components to
 zero based on vector magnitude.

Input: au, av, bmult, b, cu, cv, np, tol.

Output: du, dv, vlen, nerr.

Glossary:

au, av	Input	The u and v coordinates of point "a". Size np. The w components are zero. The directions u, v and w are orthogonal.
b	Input	Coefficient of vector "c", when multiplied by bmult.
bmult	Input	Multiplier of term $b(n) * c(n)$. Not an array.
cu, cv	Input	The u and v coordinates of point "c". Size np. The w components are zero.
du, dv	Output	The u and v components of vector "d". Size np. The w components are zero. Will be truncated to zero if less than the estimated numerical error in their calculation based on tol.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays au, av, b, cu, cv, vlen, du, dv.
tol	Input	Numerical tolerance limit. Used to truncate the components of 2-D vector $d = (du, dv)$. On Cray computers, recommend 1.e-5 to 1.e-11.
vlen	Output	Magnitude of vector "d". May be truncated to zero, if less than the estimated error in its calculation. See tol. Size np.

SUBROUTINE APTVADD

```
call aptvadd (ax, ay, az, bmult, b, cx, cy, cz, np, tol,
             dx, dy, dz, vlen, nerr)
```

Version: aptvadd Updated 1990 February 22 9:30.
 aptvadd Originated 1989 November 20 13:20.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe|x aptblibe aptvadd!end / 1 1,
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, the vector sum
 $d(n) = a(n) + bmult * b(n) * c(n)$, where $d = (dx, dy, dz)$,
 $a = (ax, ay, az)$, and $c = (cx, cy, cz)$, and to find vlen, the
 magnitude of vector "d".
 Any component of vector "d" less than the estimated error in
 its calculation, based on tol, will be truncated to zero.
 Flag nerr indicates any input error.

History: 1990 February 22. Deleted truncation of vector components to
 zero based on vector magnitude.

Input: ax, ay, az, bmult, b, cx, cy, cz, np, tol.

Output: dx, dy, dz, vlen, nerr.

Glossary:

- ax, ay, az Input The x, y, z components of vector "a". Size np.
- b Input Coefficient of vector "c", when multiplied by bmult.
- bmult Input Multiplier of term $b(n) * c(n)$. Not an array.
- cx, cy, cz Input The x, y, z components of vector "c". Size np.
- dx, dy, dz Output The x, y, z components of vector "d". Size np.
 Will be truncated to zero if less than the estimated
 numerical error in their calculation based on tol.
- nerr Output Indicates an input error, if not 0.
 1 if np is not positive.
- np Input Size of arrays.
- tol Input Numerical tolerance limit. Used to truncate
 the components of vector $d = (dx, dy, dz)$.
 On Cray computers, recommend 1.e-5 to 1.e-11.
- vlen Output Magnitude of vector "d". May be truncated to zero,
 if less than the estimated error in its calculation.
 See tol. Size np.

SUBROUTINE APTVANC

call aptvanc (au, av, bu, bv, np, tol, costh, sinth, nerr)

Version: aptvanc Updated 1990 March 14 16:00.
aptvanc Originated 1990 January 8 16:40.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe!x aptblibe aptvanc!end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the cosine costh and sine sinth of the angle between the pair of 2-D vectors $a = (au, av)$ and $b = (bu, bv)$, measured counterclockwise in the uv plane, from vector "a" to vector "b", for each of np sets of input data. The values of costh and sinth will be truncated to zero, if less than the estimated error in their calculation, based on tol. Flag nerr indicates any input error.

History: 1990 March 14. Changed tol to 0.0 in call to unit vector subroutine. Allows small magnitudes.

Input: au, av, bu, bv, np, tol.

Output: costh, sinth, nerr.

Calls: aptvaxc, aptvdoc, aptvubc
(sources in aptslibe, binaries in aptblibe).

Glossary:

au, av	Input	The u and v components of a 2-D vector. Size np.
bu, bv	Input	The u and v components of a 2-D vector. Size np.
costh	Output	Cosine of the angle between the 2-D vectors "a" and "b". Will be truncated to zero, if less than the estimated error in its calculation, based on tol. Meaningless if the magnitude of "a" or "b" is zero. The angle is measured counterclockwise in the uv plane, from vector "a" to vector "b".
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays au, av, bu, bv, costh, sinth.
sinth	Output	Sine of the angle between the 2-D vectors "a" and "b". Will be truncated to zero, if less than the estimated error in its calculation, based on tol. Meaningless if the magnitude of "a" or "b" is zero. The angle is measured counterclockwise in the uv plane, from vector "a" to vector "b".
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTVANG

call aptvang (ax, ay, az, bx, by, bz, np, tol, costh, nerr)

Version: aptvang Updated 1990 March 14 16:00.
aptvang Originated 1990 January 5 12:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptvanglend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the cosine costh of the angle between the pair of
vectors $a = (ax, ay, az)$ and $b = (bx, by, bz)$, for each of np
sets of input data. The value of costh will be truncated to
zero, if less than the estimated error in its calculation,
based on tol. Flag nerr indicates any input error.

History: 1990 March 14. Changed tol to 0.0 in call to unit vector
subroutine. Allows small magnitudes.

Input: ax, ay, az, bx, by, bz, np, tol.

Output: costh, nerr.

Calls: aptvdoc, aptvunb (sources in aptslibe, binaries in aptblibe).

Glossary:

ax,ay,az	Input	The x, y, z components of a vector. Size np.
bx,by,bz	Input	The x, y, z components of a vector. Size np.
costh	Output	Cosine of the angle between the vectors "a" and "b". Will be truncated to zero, if less than the estimated error in its calculation, based on tol.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays ax, ay, az, bx, by, bz, costh.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTVAXB

```
call aptvaxb (ax, ay, az, bx, by, bz, np, tol,
6          cx, cy, cz, vlen, nerr)
```

Version: aptvaxb Updated 1990 March 13 11:30.
 aptvaxb Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe!x aptblibe aptvaxblend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the vector products $c = (cx, cy, cz)$ of the np vector pairs $a = (ax, ay, az)$ and $b = (bx, by, bz)$, and the magnitudes $vlen$ of the vectors "c". Any components of vector "c" less than the estimated error in their calculation, based on tol , will be truncated to zero.
 Flag $nerr$ indicates any input error.

With no truncation,
 $cx = ay * bz - az * by$
 $cy = az * bx - ax * bz$
 $cz = ax * by - ay * bx.$

Input: ax, ay, az, bx, by, bz, np, tol.

Output: cx, cy, cz, vlen, nerr.

Glossary:

ax,ay,az	Input	The x, y, z components of input vector "a". Size np.
bx,by,bz	Input	The x, y, z components of input vector "b". Size np.
cx,cy,cz	Output	The x, y, z components of output vector "c". Size np. Vector (cross) product of vectors "a" and "b". Truncated to zero if less than the estimated error in their calculation. See tol.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays ax, ay, az, bx, by, bz, cx, cy, cz.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.
vlen(n)	Output	Magnitude of the vector product "c".

SUBROUTINE APTVAXC

call aptvaxc (au, av, bu, bv, np, tol, cw, nerr)

Version: aptvaxc Updated 1990 January 18 16:40.
aptvaxc Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe!x aptblibe aptvaxc!end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the vector products cw of the np 2-D vector pairs
a = (au, av) and b = (bu, bv). Vectors a and b are in the uv
plane. The directions u, v, and w are orthogonal. Any values
of cw less than the estimated error in their calculation, based
on tol, will be truncated to zero. Flag nerr indicates any
input error.

With no truncation,
$$cw = au * bv - av * bu.$$

Input: au, av, bu, bv, np, tol.

Output: cw, nerr.

Glossary:

au, av	Input	The u and v components of input vector "a". Size np. The w components are zero. Directions u, v and w are orthogonal.
bu, bv	Input	The u and v components of input vector "b". Size np. The w components are zero.
cw	Output	The w component of output vector "c". Size np. Vector (cross) product of vectors "a" and "b". The u and v components are zero. Equal to the area of the parallelogram with sides "a" and "b". Positive if the angle from "a" to "b", in the uv plane, is in the range from zero to 180 degrees. Truncated to zero if less than the estimated error in their calculation. See tol.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays au, av, bu, bv, cw.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTVDIC

call aptvdic (au, av, bu, bv, np, tol, du, dv, dab, nerr)

Version: aptvdic Updated 1990 March 7 17:00.
aptvdic Originated 1989 December 29 15:50.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe!x aptblibe aptvdic!end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, the 2-D vector $d = (du, dv)$ from point $a = (au, av)$ to point $b = (bu, bv)$, and its magnitude dab, the distance from "a" to "b", all in the uv plane. Directions u, v and w are orthogonal. Any component of vector "d" less than the estimated error in its calculation, based on tol, will be truncated to zero. Flag nerr indicates any input error.

With no truncation, $(du, dv) = (bu, bv) - (au, av)$,
and distance $dab = \text{sqrt}(du^2 + dv^2)$.

Input: au, av, bu, bv, np, tol.

Output: du, dv, dab, nerr.

Glossary:

au, av	Input	The u and v coordinates of point "a". Size np. The w coordinates are zero. Directions u, v and w are orthogonal.
bu, bv	Input	The u and v coordinates of point "b". Size np. The w coordinates are zero.
dab	Output	Distance between points "a" and "b", equal to the length of 2-D vector $d = (du, dv)$. May be truncated to zero, if less than the estimated error in its calculation. See tol. Size np.
du, dv	Output	The u and v components of 2-D vector "d". Size np. The w coordinates are zero. May be truncated to zero, if less than the estimated numerical error in their calculation based on tol.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	The size of arrays au, av, bu, bv, dab, du, dv.
tol	Input	Numerical tolerance limit. Used to truncate the components of 2-D vector $d = (du, dv)$. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTVD11

call aptvdil (au, bu, np, tol, du, nerr)

Version: aptvd1s Updated 1990 January 18 14:20.
aptvd1s Originated 1990 January 17 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe!x aptblibe aptvd1lend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, the distance
 $d = (du)$ from point $a = (au)$ to point $b = (bu)$, in the u
direction. Directions u , v and w are orthogonal.
If the magnitude of du is less than its estimated error, based
on tol , it will be truncated to zero.
Flag $nerr$ indicates any input error.

With no truncation, $du = bu - au$.

Input: au, bu, np, tol.

Output: du, nerr.

Glossary:

au	Input	The u coordinate of point "a". Size np. The v and w coordinates are zero. Directions u , v and w are orthogonal.
bu	Input	The u coordinate of point "b". Size np. The v and w coordinates are zero.
du	Output	Distance between points "a" and "b", in the u direction. May be truncated to zero, if less than the estimated error in its calculation. See tol . Size np.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	The size of arrays au, bu, du.
tol	Input	Numerical tolerance limit. On Cray computers, recommend $1.e-5$ to $1.e-11$.

SUBROUTINE APTVDIS

```
call aptvdis (ax, ay, az, bx, by, bz, np, tol,  
& dx, dy, dz, dab, nerr)
```

Version: aptvdis Updated 1990 February 22 9:30.
aptvdis Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptvdis|end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the np distance vectors $d = (dx, dy, dz)$ from the points $a = (ax, ay, az)$ to the points $b = (bx, by, bz)$, and their magnitudes, dab, the distances from "a" to "b". Any component of vector "d" less than the estimated error in its calculation, based on tol, will be truncated to zero. Flag nerr indicates any input error.

With no truncation, $(dx, dy, dz) = (bx, by, bz) - (ax, ay, az)$, and distance $dab = \sqrt{dx^2 + dy^2 + dz^2}$.

History: 1990 February 22. Deleted truncation of vector components to zero based on vector magnitude.

Input: ax, ay, az, bx, by, bz, np, tol.

Output: dx, dy, dz, dab, nerr.

Glossary:

ax,ay,az	Input	The x, y, z coordinates of point "a". Size np.
bx,by,bz	Input	The x, y, z coordinates of point "b". Size np.
dab	Output	Distance between points (ax, ay, az) and (bx, by, bz), the length of vector $d = (dx, dy, dz)$. May be truncated to zero, if less than the estimated error in its calculation. See tol. Size np.
dx,dy,dz	Output	The x, y, z components of vector "d". Size np. May be truncated to zero, if less than the estimated numerical error in their calculation based on tol.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	The size of arrays ax, ay, az, bx, by, bz, dab, dx, dy, dz.
tol	Input	Numerical tolerance limit. Used to truncate the components of vector $d = (dx, dy, dz)$. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTVDOC

call aptvdoc (au, av, bu, bv, np, tol, spab, nerr)

Version: aptvdoc Updated 1990 January 18 14:20.
aptvdoc Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibelx aptblibe aptvdoclend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the scalar (dot) product spab of the np 2-D vectors
a = (au, av) and b = (bu, bv). The value of spab will be
truncated to zero, if less than the estimated error in its
calculation, based on tol.
Flag nerr indicates any input error.

With no truncation, $spab = au * bu + av * bv$.

Input: au, av, bu, bv, np, tol.

Output: spab, nerr.

Glossary:

au, av	Input	The u and v components of a 2-D vector. Size np.
bu, bv	Input	The u and v components of a 2-D vector. Size np.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays au, av, bu, bv, spab.
spab(n)	Output	Scalar product of vectors "a" and "b". Will be truncated to zero, if less than the estimated error in its calculation, based on tol.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTVDOT

call aptvdot (ax, ay, az, bx, by, bz, np, tol, spab, nerr)

Version: aptvdot Updated 1990 January 18 14:20.
aptvdot Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe!x aptblibe aptvdot!end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the scalar (dot) product spab of the np vectors
a = (ax, ay, az) and b = (bx, by, bz). The value of
spab will be truncated to zero, if less than the estimated
error in its calculation, based on tol.
Flag nerr indicates any input error.

With no truncation, $spab = ax * bx + ay * by + az * bz$.

Input: ax, ay, az, bx, by, bz, np, tol.

Output: spab, nerr.

Glossary:

ax,ay,az	Input	The x, y, z components of a vector. Size np.
bx,by,bz	Input	The x, y, z components of a vector. Size np.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays ax, ay, az, bx, by, bz, spab.
spab(n)	Output	Scalar product of vectors "a" and "b". Will be truncated to zero, if less than the estimated error in its calculation, based on tol.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTVLIC

call aptvlic (au, av, np, tolu, tolv, vlen, nerr)

Version: aptvlic Updated 1990 January 18 14:20.
aptvlic Originated 1990 January 3 13:40.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibelx aptblibe aptvliclend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a RUILD library of Cray-compiled binaries.

Purpose: To adjust the np 2-D vectors $a = (au, av)$, by imposing the lower limits tolu and tolv on the magnitudes of the components au and av, respectively, while retaining the initial magnitude of the vector "a". If all are initially zero, the output vector "a" will be zero, and vlen will be zero. Flag nerr indicates any input error.

Input: au, av, np, tolu, tolv.

Output: au, av, vlen, nerr.

Glossary:

au, av	Input	The u and v components of input vector "a". Size np. Directions u, v and w are orthogonal.
au, av	Output	The u and v components of output vector "a". Size np. Magnitudes will be at least tolu, tolv, respectively, subject to the requirement that the final magnitude of vector "a" be the same as the initial magnitude.
nerr	Output	Indicates an input error, it not 0. 1 if np is not positive.
np	Input	Size of arrays au, av, vlen.
tolu	Input	Numerical tolerance limit for component au. On Cray computers, recommend 1.e-5 to 1.e-11.
tolv	Input	Numerical tolerance limit for component av. On Cray computers, recommend 1.e-5 to 1.e-11.
vlen(n)	Output	Magnitude of vector "a".

SUBROUTINE APTVLIM

call aptvlm (au, av, aw, np, tolu, tolv, tolw, vlen, nerr)

Version: aptvlm Updated 1990 January 18 16:40.
aptvlm Originated 1989 December 19 13:40.

Author: Arthur L. Edwards, LINL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe!x aptblibe aptvlmlend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To adjust the np vectors $a = (au, av, aw)$, by imposing the lower limits tolu, tolv, and tolw on the magnitudes of the components au, av, and aw, respectively, while retaining the initial magnitude of the vector "a". If all are initially zero, the output vector "a" will be zero, and vlen will be zero. Flag nerr indicates any input error.

Input: au, av, aw, np, tolu, tolv, tolw.

Output: au, av, aw, vlen, nerr.

Glossary:

au,av,aw Input The u, v, w components of input vector "a". Size np.

au,av,aw Output The u, v, w components of output vector "a". Size np. Magnitudes will be at least tolu, tolv, tolw, respectively, subject to the requirement that the final magnitude of vector "a" be the same as the initial magnitude.

nerr Output Indicates an input error, it not 0.
1 if np is not positive.

np Input Size of arrays au, av, aw, vlen.

tolu Input Numerical tolerance limit for component au.
On Cray computers, recommend 1.e-5 to 1.e-11.

tolv Input Numerical tolerance limit for component av.
On Cray computers, recommend 1.e-5 to 1.e-11.

tolw Input Numerical tolerance limit for component aw.
On Cray computers, recommend 1.e-5 to 1.e-11.

vlen(n) Output Magnitude of vector "a".

SUBROUTINE APTVPLC

call aptvplc (au, av, bu, bv, np, tol, cu, cv, vlen, nerr)

Version: aptvplc Updated 1990 March 13 11:30.
aptvplc Originated 1989 December 28 13:20.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptvplc|end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the vector $c = (cu, cv)$ normal to the line defined by the two points $a = (au, av)$, $b = (bu, bv)$, and in the uv plane, for each of the np sets of points "a" and "b". The directions u, v, w are orthogonal. The magnitude vlen of the normal vector "c" is equal to the length of the line segment "ab". If vlen is zero, the points "a" and "b" are congruent. By convention, the direction of the normal vector is from right to left, relative to the direction from "a" to "b" in the uv plane. The components of "c" will be truncated to zero, if less than the estimated numerical error in their calculation, based on tol.

Input: au, av, bu, bv, np, tol.

Output: cu, cv, vlen; nerr.

Glossary:

au, av	Input	The u and v coordinates of point "a". Size np.
bu, bv	Input	The u and v coordinates of point "b". Size np.
cu, cv	Output	The u and v components of normal vector "c". May be truncated to zero, if less than the estimated numerical error in their calculation. See tol.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	The number of sets of points "a" and "b" for which the normal vector "c" is to be calculated. Must be positive.
tol	Input	Numerical tolerance limit for cu, cv. On Cray computers, recommend 1.e-5 to 1.e-11.
vlen(n)	Output	The magnitude of the normal vector "c". Size np. Zero if points "a" and "b" are congruent.

SUBROUTINE APTVPLN

```
call aptvpln (ax, ay, az, bx, by, bz, cx, cy, cz, np, tol,
6 dx, dy, dz, vlen, nerr)
```

Version: aptvpln Updated 1990 March 14 11:00.
 aptvpln Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100;aptslibe / 1 1
 lib aptslibe|x aptblibe aptvplnend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the vector $d = (dx, dy, dz)$ normal to the plane defined by the three points $a = (ax, ay, az)$, $b = (bx, by, bz)$, and $c = (cx, cy, cz)$, for each of the np sets of points (a, b, c) . The magnitude $vlen$ of the normal vector "d" is equal to the area of the parallelepiped for which 3 of the vertices are (a, b, c) . If $vlen = 0$, the points (a, b, c) are congruent or collinear. The components of vector "d" will be truncated to zero, if less than the estimated numerical error in their calculation, based on tol .

History: 1990 February 22. Deleted truncation of vector components to zero based on vector magnitude.

Input: $ax, ay, az, bx, by, bz, cx, cy, cz, np, tol$.

Output: $dx, dy, dz, vlen, nerr$.

Glossary:

ax, ay, az	Input	The x, y, z coordinates of point "a". Size np .
bx, by, bz	Input	The x, y, z coordinates of point "b". Size np .
cx, cy, cz	Input	The x, y, z coordinates of point "c". Size np .
dx, dy, dz	Output	The x, y, z components of normal vector "d". May be truncated to zero, if less than the estimated numerical error in their calculation. See tol .
$nerr$	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	The number of sets of points (a, b, c) for which the normal vector "d" is to be calculated. Must be positive.
tol	Input	Numerical tolerance limit for dx, dy, dz . On Cray computers, recommend $1.e-5$ to $1.e-11$.
$vlen(n)$	Output	The magnitude of the normal vector "d". Size np . Zero if points (a, b, c) are congruent or collinear.

SUBROUTINE APTVSUC

call aptvsuc (noptf, fa, au, av, fb, bu, bv, np, tol,
 & cu, cv, clen, nerr)

Version: aptvsuc Updated 1990 April 3 16:00.
 aptvsuc Originated 1989 April 3 16:00.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe/x aptblibe aptvsuc/1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, the weighted
 sum $c = (cu, cv)$ of the vectors $a = (au, av)$ and $b = (bu, bv)$:
 $c(n) = fa * a(n) + fb * b(n)$, $n = 1, np$ (noptf = 0), or
 $c(n) = fa(n) * a(n) + fb(n) * b(n)$, $n = 1, np$ (noptf = 1),
 and to find clen, the magnitude of vector "c".
 Any component of vector "c" less than the estimated error in
 its calculation, based on tol, will be truncated to zero.
 Flag nerr indicates any input error.

Special cases:

sum: $c = a + b$ (noptf = 0, fa = 1.0, fb = 1.0).
 difference: $c = a - b$ (noptf = 0, fa = 1.0, fb = -1.0).
 bisector: $c = 0.5 * (a + b)$ (noptf = 0, fa = fb = 0.5).
 interpolation: $c = fa * a + (1.0 - fa) * b$ (noptf = 0),
 $c = (1.0 - fb) * a + fb * b$ (noptf = 0).

Input: noptf, fa, au, av, fb, bu, bv, np, tol.

Output: cu, cv, clen, nerr.

Glossary:

au,av	Input	The u and v components of vector "a". Size np.
bu,bv	Input	The u and v components of vector "b". Size np.
clen	Output	Magnitude of vector "c". May be truncated to zero, if less than the estimated error in its calculation. See tol. Size np.
cu,cv	Output	The u and v components of vector "c". Size np. Will be truncated to zero if less than the estimated numerical error in their calculation based on tol.
fa	Input	Coefficient of vector "a". Size 1 (noptf = 0) or np (noptf = 1).
fb	Input	Coefficient of vector "b". Size 1 (noptf = 0) or np (noptf = 1).
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 2 if noptf is not 0 or 1.
noptf	Input	Size option for fa, fb: 0 if fa and fb are scalars. 1 if fa and fb are arrays with size np.
np	Input	Size of arrays.
tol	Input	Numerical tolerance limit. Used to truncate the components of vector "c". On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTVSUM

```
call aptvsum (noptf, fa, ax, ay, az, fb, bx, by, bz, np, tol,
             cx, cy, cz, clen, nerr)
```

Version: aptvsum Updated 1990 April 3 13:20.
 aptvsum Originated 1989 April 3 13:20.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe|x aptblibe aptvsumlend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, the weighted sum $c = (cx, cy, cz)$ of the vectors $a = (ax, ay, az)$ and $b = (bx, by, bz)$:
 $c(n) = fa * a(n) + fb * b(n)$, $n = 1, np$ (noptf = 0), or
 $c(n) = fa(n) * a(n) + fb(n) * b(n)$, $n = 1, np$ (noptf = 1),
 and to find clen, the magnitude of vector "c".
 Any component of vector "c" less than the estimated error in its calculation, based on tol, will be truncated to zero.
 Flag nerr indicates any input error.

Special cases:

sum: $c = a + b$ (noptf = 0, fa = 1.0, fb = 1.0).
 difference: $c = a - b$ (noptf = 0, fa = 1.0, fb = -1.0).
 bisector: $c = 0.5 * (a + b)$ (noptf = 0, fa = fb = 0.5).
 interpolation: $c = fa * a + (1.0 - fa) * b$ (noptf = 0),
 $c = (1.0 - fb) * a + fb * b$ (noptf = 0).

Input: noptf, fa, ax, ay, az, fb, bx, by, bz, np, tol.

Output: cx, cy, cz, clen, nerr.

Glossary:

ax,ay,az	Input	The x, y, z components of vector "a". Size np.
bx,by,bz	Input	The x, y, z components of vector "b". Size np.
clen	Output	Magnitude of vector "c". May be truncated to zero, if less than the estimated error in its calculation. See tol. Size np.
cx,cy,cz	Output	The x, y, z components of vector "c". Size np. Will be truncated to zero if less than the estimated numerical error in their calculation based on tol.
fa	Input	Coefficient of vector "a". Size 1 (noptf = 0) or np (noptf = 1).
fb	Input	Coefficient of vector "b". Size 1 (noptf = 0) or np (noptf = 1).
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive. 2 if noptf is not 0 or 1.
noptf	Input	Size option for fa, fb. 0 if fa and fb are scalars. 1 if fa and fb are arrays with size np.
np	Input	Size of arrays.
tol	Input	Numerical tolerance limit. Used to truncate the components of vector "c". On Cray computers, recommend 1.e-5 to 1.e-11.

SUBROUTINE APTVTOC

call aptvtoc (au, av, np, kadj, knorm, tolu, tolv, vlen, nerr)

Version: aptvtoc Updated 1990 January 18 14:20.
 aptvtoc Originated 1989 November 15 16:40.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100;aptslibe / 1 1
 lib aptslibe|x aptblibe aptvtoclend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To adjust the values of the components of the np 2-D vectors
 a = (au, av), according to the option kadj, and the
 numerical tolerance limits tolu and tolv, and to
 renormalize to a unit vector if option knorm = 1.
 Flag nerr indicates any input error.

Input: au, av, np, kadj, knorm, tolu, tolv.

Output: au, av, vlen, nerr.

Glossary:

au, av	Input	The u and v components of input vector "a". Size np. Directions u, v and w are orthogonal.
au, av	Output	The u and v components of output vector "a". Size np. May be adjusted, according to the option kadj, and the numerical tolerance limits tolu and tolv.
nerr	Output	Indicates an input error, it not 0. 1 if np is not positive. 2 if kadj is not from 0 to 7. 3 if knorm is not 0 or 1.
kadj	Input	Option for adjusting the components (au, av). Values from 0 to 7 are allowed: 0 to use a limiting value equal to the tolerance limit times the vector magnitude. Add 1 to use a limiting value equal to the tolerance limit. Add 0 to use the same tolerance limit, tolu, for au and av. Add 2 to use tolu for au, tolv for av. Add 0 to truncate the component to zero if less than the limiting value. Add 4 to increase components less than the limiting value, to the limiting value, with the same sign.
knorm	Input	Option for normalizing the adjusted vector "a" to a unit vector. 0 = no, 1 = yes.
np	Input	Size of arrays au, av, vlen.
tolu	Input	Numerical tolerance limit for component au, and for au and av, for kadj = 0, 1, 4, and 5. On Cray computers, recommend 1.e-5 to 1.e-11.
tolv	Input	Numerical tolerance limit for component av, for kadj = 2, 3, 6, and 7. On Cray computers, recommend 1.e-5 to 1.e-11.
vlen(n)	Output	Magnitude of the input vector "a", after any adjustment of components has been done, but before any renormalization (knorm = 1). Will be zero if all components of "a" are zero, or are truncated to zero.

SUBROUTINE APTVTOL

```
call aptvtol (ax, ay, az, np, kadj, knorm, tolx, toly, tolz,
&            vlen, nerr)
```

Version: aptvtol Updated 1990 January 18 16:40.
 aptvtol Originated 1989 November 15 16:40.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe!x aptblibe aptvtollend / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To adjust the values of the components of the np vectors
 a = (ax, ay, az), according to the option kadj, and the
 numerical tolerance limits tolx, toly, tolz, and to
 renormalize to a unit vector if option knorm = 1.
 Flag nerr indicates any input error.

Input: ax, ay, az, np, kadj, knorm, tolx, toly, tolz.

Output: ax, ay, az, vlen, nerr.

Glossary:

ax,ay,az	Input	The x, y, z components of input vector "a". Size np.
ax,ay,az	Output	The x, y, z components of output vector "a". Size np. May be adjusted, according to the option kadj, and the numerical tolerance limits tolx, toly, tolz.
nerr	Output	Indicates an input error, it not 0. 1 if np is not positive. 2 if kadj is not from 0 to 7. 3 if knorm is not 0 or 1.
kadj	Input	Option for adjusting the components (ax, ay, az). Values from 0 to 7 are allowed: 0 to use a limiting value equal to the tolerance limit times the vector magnitude. Add 1 to use a limiting value equal to the tolerance limit. Add 0 to use the same tolerance limit, tolx, for ax, ay, and az. Add 2 to use tolx for ax, toly for ay, and tolz for az. Add 0 to truncate the component to zero if less than the limiting value. Add 4 to increase components less than the limiting value, to the limiting value, with the same sign.
knorm	Input	Option for normalizing the adjusted vector "a" to a unit vector. 0 = no, 1 = yes.
np	Input	Size of arrays ax, ay, az, vlen.
tolx	Input	Numerical tolerance limit for component ax, and for ax, ay and az, for kadj = 0, 1, 4, and 5. On Cray computers, recommend 1.e-5 to 1.e-11.
tolx	Input	Numerical tolerance limit for component ay, for kadj = 2, 3, 6, and 7. On Cray computers, recommend 1.e-5 to 1.e-11.
tolz	Input	Numerical tolerance limit for component az, for kadj = 2, 3, 6, and 7. On Cray computers, recommend 1.e-5 to 1.e-11.
vlen(n)	Output	Magnitude of the input vector "a", after any adjustment of components has been done, but before any renormalization (knorm = 1). Will be zero if all components of "a" are zero, or are truncated to zero.

SUBROUTINE APTVUAC

call aptvuac (au, av, np, tol, vlen, nerr)

Version: aptvuac Updated 1990 March 14 17:30.
aptvuac Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe:x aptblibe aptvuac:lend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the np unit vectors $a = (au, av)$ parallel to the np
initial vectors $a = (au, av)$, all in the uv plane (2-D). Any
components of the initial vector "a" no greater than tol, or no
greater than tol times the initial length of "a", will be
truncated to zero. If all are zero, or are truncated to zero,
vlen will be zero.
Flag nerr indicates any input error.

With no truncation,
 $(au, av) = (au, av) / \text{sqrt}(au**2 + av**2)$

History: 1990 March 14. Modified to always return a unit vector.

Input: au, av, np, tol.

Output: au, av, vlen, nerr.

Glossary:

au, av	Input	The u and v components of initial vector "a" in the uv plane. Size np. Will be truncated to zero if initially no greater than tol, or no greater than tol times the initial length of "a".
au, av	Output	The u and v components of unit vector "a" in the uv plane. Size np.
nerr	Output	Indicates an input error, 1 if not 0. 1 if np is not positive.
np	Input	Size of arrays au, av, vlen.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.
vlen(n)	Output	Magnitude of the input vector "a", after any truncation of components has been done, but before division by vlen to form a unit vector.

SUBROUTINE APTVUBC

call aptvubc (au, av, np, tol, bu, bv, vlen, nerr)

Version: aptvubc Updated 1990 March 14 17:30.
aptvubc Originated 1989 November 29 10:00.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe!x aptblibe aptvubc!end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the np unit vectors $b = (bu, bv)$ parallel to the np vectors $a = (au, av)$, all in the uv plane (2-D). If any components of the initial vector "a" are no greater than tol, or no greater than tol times the initial length of "a", then the corresponding component of "b" will be truncated to zero. If all are zero, or are truncated to zero, vlen will be zero. Flag nerr indicates any input error.

With no truncation,
 $(bu, bv) = (au, av) / \text{sqrt}(au**2 + av**2)$

History: 1990 March 14. Modified to always return a unit vector.

Input: au, av, np, tol.

Output: bu, bv, vlen, nerr.

Glossary:

au, av	Input	The u and v components of vector "a" in the uv plane. Size np.
bu, bv	Output	The u and v components of vector "b" in the uv plane. Size np. A component will be zero if the corresponding component of vector "a" is no greater than tol, or no greater than tol times the length of "a".
nerr	Output	Indicates an input error, it not 0. 1 if np is not positive.
np	Input	Size of arrays au, av, bu, bv, vlen.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.
vlen(n)	Output	Magnitude of vector "b", after any truncation of components has been done, but before division by vlen to form a unit vector.

SUBROUTINE APTVUNA

call aptvuna (ax, ay, az, np, tol, vlen, nerr)

Version: aptvuna Updated 1990 March 14 17:30.
aptvuna Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptvuna|end / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the np unit vectors $a = (ax, ay, az)$ parallel to the
np initial vectors $a = (ax, ay, az)$. Any components of the
initial vector "a" no greater than tol, or no greater than tol
times the initial length of "a", will be truncated to zero.
If a.l are zero, or are truncated to zero, vlen will be zero.
Flar nerr indicates any input error.

With no truncation,

$$(ax, ay, az) = (ax, ay, az) / \text{sqrt} (ax**2 + ay**2 + az**2).$$

History: 1990 March 14. Modified to always return a unit vector.

Input: ax, ay, az, np, tol.

Output: ax, ay, az, vlen, nerr.

Glossary:

ax,ay,az	Input	The x, y, z components of input vector "a". Size np. Will be truncated to zero if initially no greater than tol, or no greater than tol times the initial length of "a".
ax,ay,az	Output	The x, y, z components of unit vector "a". Size np.
nerr	Output	Indicates an input error, it not 0. 1 if np is not positive.
np	Input	Size of arrays ax, ay, az, vlen.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.
vlen(n)	Output	Magnitude of the input vector "a", after any truncation of components has been done, but before division by vlen to form a unit vector.

SUBROUTINE APTVUNB

call aptvunb (ax, ay, az, np, tol, ux, uy, uz, vlen, nerr)

Version: aptvunb Updated 1990 March 21 15:50.
aptvunb Originated 1989 November 2 14:10.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptblibe aptvunblend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the np unit vectors $u = (ux, uy, uz)$ parallel to the np vectors $a = (ax, ay, az)$. If any component of vector "a" is no greater than tol, or no greater than tol times the length of "a", then the corresponding component of "u" will be truncated to zero. If all are zero, or are truncated to zero, vlen will be zero. Flag nerr indicates any input error.

With no truncation,

$$(ux, uy, uz) = (ax, ay, az) / \text{sqrt}(ax**2 + ay**2 + az**2).$$

History: 1990 March 14. Modified to always return a unit vector.
1990 March 21. Deleted change of 1990 March 14.

Input: ax, ay, az, np, tol.

Output: ux, uy, uz, vlen, nerr.

Glossary:

ax,ay,az	Input	The x, y, z components of a vector. Size np.
nerr	Output	Indicates an input error, it not 0. 1 if np is not positive.
np	Input	Size of arrays ax, ay, az, ux, uy, uz, vlen.
ux,uy,uz	Output	The x, y, z components of a unit vector. Size np. A component will be zero if the corresponding component of vector "a" is no greater than tol, or no greater than tol times the length of "a".
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.
vlen(n)	Output	Magnitude of vector "u", after any truncation of components has been done, but before division by vlen to form a unit vector.

SUBROUTINE APTVXUC

call aptvxuc (au, av, bu, bv, np, tol, cw, vlen, nerr)

Version: aptvxuc Updated 1990 January 18 14:20.
 aptvxuc Originated 1989 December 29 11:00.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read ,245100:aptslibe / 1 1
 lib aptslibe\k aptblibe aptvxuc\end / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find, for each of the np sets of input data, the vector
 (cross) product "a" x "b" of the pair of 2-D vectors
 a = (au, av) and b = (bu, bv), and to divide by its
 magnitude vlen, to produce the unit vector c = (0.0, 0.0, cw),
 parallel to "a" x "b". If cw is less than the estimated error
 in its calculation, based on tol, it will be truncated to zero,
 and vlen will be zero. Directions u, v and w are orthogonal.
 Flag nerr indicates any input error.

Input: au, av, bu, bv, np, tol.

Output: cw, vlen, nerr.

Glossary:

au, av	Input	The u and v components of input vector "a". Size np. The w components are zero. The unit vectors in the directions u, v and w form a positive unit triple.
bu, bv	Input	The u and v components of input vector "b". Size np. The w components are zero.
cw	Output	The w components of output vector "c". Size np. Will usually be +1.0 or -1.0. The u and v components are zero. Vector (cross) product of vectors "a" and "b", normalized to unit magnitude. The value of cw will be truncated to zero if less than the estimated error in its calculation, based on tol. This indicates that "a" and "b" are essentially parallel.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays au, av, bu, bv, cw, vlen.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.
vlen(n)	Output	Magnitude of the vector product "a" x "b", after any truncation of components has been done. Will be zero if all components of vector "c" are zero. Size np.

SUBROUTINE APTVXUN

```
call aptvxun (ax, ay, az, bx, by, bz, np, tol,
             ux, uy, uz, vlen, nerr)
```

Version: aptvxun Updated 1990 March 14 16:00.
 aptvxun Originated 1989 November 10 11:20.

Author: Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
 lib aptslibe|x aptblibe aptvxun|end / 1 1.
 aptslibe is a LIB library of FORTRAN source files.
 aptblibe is a BUILD library of Cray-compiled binaries.

Purpose: To find the vector products "a" x "b" of the np vector pairs
 $a = (ax, ay, az)$ and $b = (bx, by, bz)$, and divide by their
 magnitudes vlen, to produce the unit vectors $u = (ux, uy, uz)$,
 parallel to "a" x "b". Any components of vector "u" less than
 the estimated error in their calculation, based on tol, will be
 truncated to zero. If all are zero, or are truncated to zero,
 the output vector "u" will be zero, and vlen will be zero.
 Flag nerr indicates any input error.

History: 1990 March 14. Changed tol to 0.0 in call to unit vector
 subroutine. Allows small magnitudes.

Input: ax, ay, az, bx, by, bz, np, tol.

Output: ux, uy, uz, vlen, nerr.

Calls: aptvuna (source in aptslibe, binary in aptblibe).

Glossary:

ax,ay,az	Input	The x, y, z components of input vector "a". Size np.
bx,by,bz	Input	The x, y, z components of input vector "b". Size np.
ux,uy,uz	Output	The x, y, z components of output vector "u". Size np. Vector (cross) product of vectors "a" and "b", normalized to unit magnitude. A component will be truncated to zero if less than the estimated error in its calculation, based on tol.
nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
np	Input	Size of arrays ax, ay, az, bx, by, bz, ux, uy, uz, vlen.
tol	Input	Numerical tolerance limit. On Cray computers, recommend 1.e-5 to 1.e-11.
vlen(n)	Output	Magnitude of the vector product "a" x "b", after any truncation of components has been done. Will be zero if all components of vector "u" are zero. Size np.

SUBROUTINE APTXNUP

call aptxnup (nopt, tplanck, np, xnu, nerr)

Version: aptxnup Updated 1990 February 12 10:50.
aptxnup Originated 1990 January 31 17:00.

Authors: Eugene H. Canfield, LLNL, L-298, Telephone (415) 422-4125.
Arthur L. Edwards, LLNL, L-298, Telephone (415) 422-4123.

Source: xport read .245100:aptslibe / 1 1
lib aptslibe|x aptslibe aptknuplend / 1 1.
aptslibe is a LIB library of FORTRAN source files.
aptslibe is a BUIID library of Cray-compiled binaries.

Purpose: To find, for each of np temperatures tplanck, a frequency xnu
sampled randomly from a Planck or a Wien spectrum.
Flag nerr indicates any input error (np not positive).

The Planck distribution function is:
 $p(x) = (15.0 / \pi^{**4}) * x^{**3} / (\exp(x) - 1.0)$,
where $x = xnu / tplanck$, and $\langle x \rangle = 3.83223...$
The Wien distribution function is:
 $p(x) = x^{**3} * \exp(-x) / 6.0$,
where $\langle x \rangle = 4.0$.

History: See Barnett and Canfield, UCIR-473, June 1970.
1990 February 6 11:20, Truncated plfn, to limit number of terms
required to converge.

Input: nopt, tplanck, np.

Output: xnu, nerr.

Glossary:

nerr	Output	Indicates an input error, if not 0. 1 if np is not positive.
nopt	Input	Indicates type of spectrum to sample from: 0 for a Planck spectrum. 1 for a Wien spectrum.
np	Input	Size of arrays tplanck, xnu.
tplanck	Input	Black body temperature of frequency distribution. Same units as xnu. Size np.
xnu	Output	Frequency sampled randomly from spectrum. Size np. Same units as tplanck.

APPENDIX

SUBROUTINES BY FUNCTION

FUNDAMENTAL CONSTANTS

Find the values of the fundamental constants of Physics and Chemistry, and energy conversion factors

in cm-g-sec-keV units	aptconl
in m-kg-s (SI) units	aptconm

MATHEMATICS AND STATISTICS

Find any real root of a general quadratic equation

a single equation	aptqrts
any number of equations (vectorized)	aptqrtv

Find the mean and standard deviation of a set of values

aptmean

MONTE CARLO SAMPLING

Sample randomly from a probability distribution

values from a linear distribution on an interval	aptslid
one value from each linear distribution on an interval	aptsliv
points in a major plane (2-D)	
uniformly in a triangle	apttloc
uniformly in a triangle or quadrangle	aptqloc
direction vectors in any coordinate system (3-D)	
uniform distribution	aptscat
cosine-power distribution along a specified axis	aptscap
direction vectors in a specified plane (3-D)	
uniform distribution	aptscad
frequencies from a Planck or a Wien spectrum	aptxnup
velocities from a relativistic Maxwellian distribution	aptmaxw

FUZZY GEOMETRY

Impose limits on the values of

a fractional distance (scalar)	aptfdad
any number of fractional distances (vectorized)	aptfdav
the components of a vector	
in a major plane (2-D), lower	aptvlic
in a major plane (2-D), several options	aptvloc
in any coordinate system (3-D), lower	aptvlim
in any coordinate system (3-D), several options	apvtol

Round off a floating point number

to a specified relative or absolute precision	aptrnds
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GEOMETRY

Transform between Cartesian, cylindrical and spherical coordinate systems

coordinates (3-D) aptcsys
coordinates and bound vectors (3-D) aptcsyv

Do the basic vector operations

linear combination
in a major plane (2-D) aptvadc
in a major plane (2-D) aptvsuc
in any coordinate system (3-D) aptvadd
in any coordinate system (3-D) aptvsum
difference
in a major plane (2-D) aptvdic
in any coordinate system (3-D) aptvdis
dot (scalar) product
in a major plane (2-D) aptvdoc
in any coordinate system (3-D) aptvdot
cross (vector) product
in a major plane (2-D) aptvaxc
in a major plane (2-D), normalized to unit vector aptvxuc
in any coordinate system (3-D) aptvaxb
in any coordinate system (3-D), normalized aptvxun
normalize to a unit vector
in a major plane (2-D) aptvubc
in a major plane (2-D), replace aptvuac
in any coordinate system (3-D) aptvunb
in any coordinate system (3-D), replace aptvuna

Do the basic matrix operations

product of a 3-D vector and a 3 by 3 matrix aptmopv
product of two n by n matrices aptmprd

Find the angle relationships

area included between adjacent sides
in a major plane (2-D) aptvaxc
in any coordinate system (3-D) aptvaxb
bisectors
in a major plane (2-D) aptbanc
in any coordinate system (3-D) aptbang
cosine
in any coordinate system (3-D) aptvang
cosine (between unit vectors)
in a major plane (2-D) aptvdoc
in any coordinate system (3-D) aptvdot
cosine and sine
in a major plane (2-D) aptvanc
sine (between unit vectors)
in a major plane (2-D) aptvaxc
in any coordinate system (3-D) aptvaxb

Test for the special geometric relationships

points being coincident	
on an axis (1-D)	aptvdl1
in a major plane (2-D)	aptvdlc
in xyz space (3-D)	aptvdis
in any coordinate system (3-D)	aptdist
points being on lines	
in a major plane (2-D)	aptplic
in xyz space (3-D)	aptplin
points being within a bounded region	
in a major plane (2-D)	
a triangle, and distances to sides	apttinc
a quadrangle, and distances to sides	aptpinc
lines being parallel or congruent	
in a major plane (2-D)	aptninc
in xyz space (3-D)	aptnlin
line being in a plane	
in xyz space (3-D)	aptnlpl
vectors being parallel	
in a major plane (2-D)	aptvaxc
in any coordinate system (3-D)	aptvaxb
vectors being perpendicular	
in a major plane (2-D)	aptvdoc
in any coordinate system (3-D)	aptvdot
planes being parallel or congruent	
in xyz space (3-D)	aptpplpl
plane being tangent to a sphere	
in xyz space (3-D)	aptppls
spheres being congruent	
in xyz space (3-D)	aptspsp
sphere being tangent to a sphere	
in xyz space (3-D)	aptspsp

Do the basic geometric operations

inversion of a point or vector through a specified point	
in a major plane (2-D)	aptinvc
in xyz space (3-D), and the operator	aptinvp
in xyz space (3-D), with scaling, and the operator	aptsclu
linear scaling of a point or vector in the direction of a specified axis (i.e., Lorentz transformation)	
in a major plane (2-D)	aptsclc
in xyz space (3-D), and the operator	aptscll
in xyz space (3-D), with reflection, and the operator	aptscll
uniform scaling of a point or vector	
in xyz space (3-D), and the operator	aptsclu
in xyz space (3-D), with inversion, and the operator	aptsclu
reflection of a point or vector	
from a plane perpendicular to a major plane (3-D)	
of a point or vector in a major plane (2-D)	aptrerc
of a point or vector in xyz space (3-D)	aptrerfl
from a plane in xyz space (3-D), and the operator	aptrerfs

rotation of a point or vector	
by a specified angle around a specified axis	
in a major plane (2-D)	aptrrotc
in xyz space (3-D), operator only	aptrrota
by specified angles around the 3 major axes (3-D),	
operator only	aptrrots
to rotate a specified vector onto another vector	
(3-D), operator only	aptrrotv
to rotate a specified plane onto another plane	
(3-D), operator only	aptrrotp
to rotate a specified vector in a specified plane	
onto another vector in another plane (3-D),	
operator only	aptrrott
apply the operator generated by aptrrota, aptrrotp,	
aptrrots, aptrrott, aptrrotv or aptmopv to points	
or vectors	aptmopv
translation of a point	
in a major plane (2-D)	aptrtrac
in xyz space (3-D)	aptrtran
combined operations	
multiply two matrix operators together	aptrmprd
apply matrix operator to points or vectors	aptmopv

Find the distance

from a point to another point	
on an axis (1-D)	aptrvdil
in a major plane (2-D), and direction	aptrvdic
in xyz space (3-D), and direction	aptrvdis
in any coordinate system (3-D), and direction	aptrvdist
from a point to a line	
in a major plane (2-D)	aptrptlc
in xyz space (3-D)	aptrptln
from a point to the sides of a triangle	
in a major plane (2-D), and in or out?	aptrttinc
from a point to the sides of a quadrangle	
in a major plane (2-D)	aptrqdic
in a major plane (2-D), and in or out?	aptrqinc
from a point to a plane in xyz space (3-D)	
in any orientation, and the nearest point	aptrptpl
bounded by a triangle, and the nearest point, more	aptrtrip
from a point to a second-order surface	
bounded by a quadrangle (3-D), and the nearest point	aptrquad
from a line to another line	
in a major plane (2-D)	aptrlnlc
in xyz space (3-D)	aptrlnln
from a line to a plane	
in xyz space (3-D)	aptrlnpl

Find the initial vector direction between two points

in a major plane (2-D), and find distance	aptrvdic
in xyz space (3-D), and find distance	aptrvdis
in any coordinate system (3-D), and find distance	aptrvdist

Find the alternate geometric representation of a

line in a major plane (2-D)	
given two points, find vector, distance	aptvdic
given point and vector, find another point	aptvadc
line in xyz space (3-D)	
given two points, find vector, distance	aptvdis
given point and vector, find another point	aptvadd
line in any coordinate system (3-D)	
given two points, find initial vector, distance	aptdist
plane in xyz space (3-D)	
given three points, find normal vector	aptvpln

Find the vector perpendicular (normal) to a

line in a major plane (2-D)	aptvplc
plane in xyz space (3-D)	aptvpln

Find the vertex areas in a major plane (2-D) of a

triangle	aptvaxc
quadrangle, and shape (convex, boomerang, bowtie)	aptvqac

Find the local coordinates of a point

in a quadrangle in a major plane (2-D), with any number of points, one quadrangle	aptvqdc
in a quadrangle in a major plane (2-D), with any number of points, quadrangles	aptvfdq

Find the intersection(s) of a line with

a line in a major plane (2-D)	apvtnlc
a circle in a major plane (2-D) (two points)	apvtnic
a plane in xyz space (3-D)	apvtnpl

Find the intersection(s) of a linear track with

a line, both in a major plane (2-D)	apvtrklc
a major plane (3-D)	apvtrksl
a plane in xyz space (3-D)	apvtrkpl
an axisymmetric cylindrical surface with constant radius (3-D)	apvtrkcl
an axisymmetric cylindrical surface (3-D)	apvtrkcy
a centrisymmetric spherical surface (3-D)	apvtrkrl
a general implicit second-order surface (3-D)	apvtrkis

Find the intersection(s) between

two circles in a major plane (2-D) (2 points)	apvcinc
two planes in xyz space (3-D) (a line)	apvplpl
a plane and a sphere in xyz space (3-D) (a circle)	apvplsp
two spheres in xyz space (3-D) (a circle)	apvspps

Move a point a specified distance in a specified direction, and find the final position, direction

in any coordinate system (3-D)

in axisymmetric cylindrical coordinates (3-D)

in spherical coordinates (3-D)

aptmov

aptmvcy

aptmovs

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END

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