Nonlinear theory of elementary particles
3.The mass origin theory

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Two hypotheses of the mass origin are examined: 1) the theory of mass, developed within the framework of electron theory, and 2) Higgs's mechanism of the mass generation of Standard Model. The advantages and disadvantages of each of them are shown. The connections between these two approaches and nonlinear theory of elementary particles are also noted.

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1.0. Introduction."*The garbage of the past often becomes the treasure of the present (and vice versa)*".

"*We have no better way of describing elementary particles than quantum field theory. A quantum field in general is an assembly of an infinite number of interacting harmonic oscillators. Excitations of such oscillators are associated with particles…*

All this has the flavour of the XIX century, when people tried to construct mechanical models for all phenomena. I see nothing wrong with it because any nontrivial idea is in a certain sense correct. The garbage of the past often becomes the treasure of the present (and vice versa). For this reason we shall boldly investigate all possible analogies together with our main problem…

Elementary particles existing in nature resemble very much excitations of some complicated medium (aether). We do not know the derailed structure of the aether but we have learned a lot about effective Lagrangians for its low energy excitations."

A.M. Polyakov. Gauge Fields and Strings. Harwood Academic Publishers, 1987.

Two theories of the origin of the masses of elementary particles were developed until present time.

The first was created at the end of 19^{th} century within the framework of classical (i.e. pre-quantum) physics, and it is called electron theory. There it was assumed that the mass of the electron and other electrified bodies has electromagnetic origin.

Another theory arose at the end of 20^{th} century within the framework of the Standard Model theory and it is called the theory of the spontaneous breaking of gauge symmetry or briefly Higgs's mechanism.

Both theories have general initial basis: it is considered that the mass is occurs due to interaction of a material particle with a certain nonmaterial medium (or more precisely, with the medium, in which there are no material particles). In the electron theory this medium is called electromagnetic aether. In the Standard Model this medium is one of the forms of the so-called physical vacuum, namely Higgs's vacuum, which possesses the property of being spontaneously converted to the state, in which mass-free particles become massive.

As it will be evident from the following chapters, the theory of the mass origin, proposed within the framework of the nonlinear theory of elementary particles (NTEP), has close connections both with the first and with the second theory. Therefore the analysis of the existing theories of the generation of masses is useful not only by itself, but also for further development of this issue within the framework of nonlinear theory.

Before passing to the examination of abovementioned theories, it is necessary to note two serious factors. The first of them consists in the fact that the language of science, as generally the language of people, changes continuously. Therefore many old concepts have a different name today, and we think that they have no connection with the previous ones. With the sequential analysis it is revealed that the majority of contemporary concepts originate from previous concepts and are only their redesignation.

The second factor is even more important. For specific reasons the development of the classical theory of mass stopped at the beginning of the 20th century. During the following period, since 1926 (by this year last works on this area are dated) until our times within the framework of a new quantum approach in this region, an enormous volume of additional information is accumulated.

It is sufficient say that up to the 20th century the electron was the only known elementary particle. The mathematical circumscription of classical electron from a contemporary point of view is extremely simplified. Before 1926 the electron equations of Schroedinger and Dirac and all consequences of the quantum theory of electron were unknown. Classical electron does not have a connection with the quantum theory: it does not have a momentum (spin) and a magnetic moment, it cannot be stable, and so forth. It was already at that time understandable that the classical theory is clearly incomplete. Nevertheless, within its framework a number of very meaningful results was obtained, which became the basis of contemporary physics.

For the comparison of each ideas in the question of the mass origin, we will use brief quotations from books and articles of the well-known scholars, accompanied by small commentaries. For additional information on the questions examined, the reader can become familiar with books and publications, indicated in the bibliography of this article.

2.0. The electron theory

Electron theory (The Great Soviet Encyclopedia, 1970-1979) in the broad sense is the generalization of Maxwell's theory, called Maxwell- Lorentz electrodynamics. In vacuum its equations coincide with the Maxwell equations.

"Maxwell-Lorentz equations are the fundamental equations of classical electrodynamics describing the microscopic electromagnetic fields generated by individual charged particles. The Maxwell-Lorentz equations were obtained as a result of a generalization of the macroscopic Maxwell equations. According to the electron theory, Maxwell-Lorentz equations accurately describe the fields at any point in medium and space (including interatomic and intraatomic fields and even the fields within an electron) at any point in time. In Lorentz' theory all charges are divided into free charges and bound charges (which are part of electrically neutral atoms and molecules).

Lorentz' electron theory has made it possible to clarify the physical meaning of the fundamental constants that enter into the Maxwell equations and that characterize the electrical and magnetic properties of matter. Certain important electrical and optical phenomena, such as the normal Zeeman effect, the dispersion of light, and the properties of metals and dielectrics, were predicted or explained on the basis of this theory."

The "electron theory" in the narrow sense is the first theory of field and elementary particles, in which as the object of investigation was the first elementary particle - electron. Since the electron is an electrically charged particle, as the field theory, in which it was examined, became the electromagnetic theory of Maxwell (expanded by Lorentz this theory is known as Maxwell-Lorentz theory).

Many books published until 1926 (some of them were republished later) are devoted to the electron theory (Lorentz, 1953; Becker, 1982; Richardson, 1916; and so forth). In the newest literature to this theme special attention is given to "Classical electrodynamics" of J.D. Jackson,

(Jackson, 1999) and to the lecture about electrodynamics of (Feynman et al, 1964). Therefore we omit all details and suggest that the reader to revert to the corresponding reference.

Electron theory was designed in the sufficiently final form in the works of Lorentz, but in its development participated many great physicists. The following were the basic hypotheses of this theory:

1) there is an electromagnetic medium, called electromagnetic (EM) aether, in which there are no matterial bodies. In the contemporary theory of elementary particles a similar medium is called "the field in the lowest energy state" or "physical vacuum". For EM aether Maxwell-Lorentz equations without the sources or the equation of electromagnetic waves are valid.

2) Electron is not a particle of EM aether, but it is a certain modification (concentration, clot or, according to A. Einstein, condensation) of the electromagnetic field of aether. Electron consists of the electrical (in the later versions of the beginning of 20th century, electromagnetic) field, concentrated in some volume of space. It is a continuous field distribution and therefore it does not have specific boundaries in a mechanical sense, but the field distribution of electron is characterized by specific sizes. Nothing was known about the structure of electron or the method of the appearance of electron. Therefore an evenly charged (over the surface or by volume) ball was initially accepted as the model of electron.

3) all neutral bodies (atoms) consist of positive and negative charges, similar to electron, whose charges are compensated;

4) all interactions in nature, which connect atoms and molecules between themselves, are electromagnetic (i.e. in other words, they are described by Lorentz's force).

In the 19th century there was no experimental proof of these hypotheses, but the calculations, made on the basis of electron theory, in essence, were confirmed by experiments. The experimental and theoretical results, obtained in the past century, showed the validity of these hypotheses; today we can assert with good reason that they are accurate. Let us enumerate some of these results.

The equation of photon - the quantum of electromagnetic wave – is, taking into account the quantization of its energy, the Maxwell equation (see Akhiezer and Berestetskii, 1965, Levich et al, 1973; Kyriakos, 2010c)

The equation of Dirac's electron, which with huge accuracy describes the characteristics of electron, proved to be the nonlinear electromagnetic equation, whose all characteristics have electromagnetic origin (see Kyriakos, 2004b)). The same goes for all leptons, since in the bispinor form the Dirac equation describes also other leptons (see Kyriakos, 2005).

It is proven that all remaining elementary particles - hadrons - and their interactions have electromagnetic origin. The contemporary theory of hadrons is based on Yang- Mills equations, which, as it is repeatedly noted, are the nonlinear generalizations of Maxwell's equations (Nambu, 1962): "*The generalization of the Maxwell theory is the theory of the Yang-Mills fields or non-Abelian gauge fields. Its equations are nonlinear. In contrast to this, the equations of Maxwell are linear, in other words, Abelian*".

It is also proven that all fundamental particles (leptons and quarks) are structureless particles. Since the description of such particles does not contain their geometric dimension, such particles are also called point particles.

By theoretical calculations and by experiments it is also confirmed that interactions of atoms and molecules are electromagnetic (Gottfried and Weisskopf, 1984):

"6. The electromagnetic nature of atomic phenomena

The most important consequence of the a application of quantum mechanics to atomic systems is the recognition that all properties of atoms, molecules, and their aggregates, can be understood by assuming that an atom is a system consisting of a nucleus…with a charge Ze, and of Z electrons, each of charge –e, with interaction between these constituents being solely due to the electromagnetic fields produced by the charges… This dynamical problem is simple in principle; … It is not simple in practice…Nevertheless, we are certain that all the interatomic and intermolecular forces… are manifestations of the electromagnetic interactions between the *constituents, among which the electrostatic attraction or repulsion (Coulomb force) plays the dominant role. Since almost all natural phenomena… are due to interactions between atoms, we conclude that these phenomena are all consequences of the electromagnetic interaction between nuclei and electrons, and of quantum mechanics".*

The results of electron theory, taking into consideration scant experimental data, which physics had at the end of the 19th century, were very important. It was discovered, that the energy field distribution of electron is characterized by a certain size, which was conditionally called classical radius of electron.

Electron motion as electrical body, was completely described by the electromagnetic theory. It was shown that without the action of forces the electron moves by the inertia, since all forces in it are balanced. In the case of accelerated motion the self-forces, which hamper the motion, appear.

According to electrodynamics the accelerated electron must emit electromagnetic waves. assuming that a pair of opposite charges - electron and atomic nucleus - can be examined as dipole with the harmonically oscillated charges, Lorentz constructed the dipole theory of electron emission of the atom. His theory of the emission of EM waves from hydrogen atoms coincides precisely with the quantum theory of the emission of photons by hydrogen atoms, developed considerably later. On this base were explained many effects of emission of light by atoms (Zeeman effect and others).

But Lorentz made even more important discoveries, investigating electron motion relatively to EM aether. These discoveries were made on the border of two branches of physics: electrodynamics and mechanics, i.e., on the border, that divides electrified bodies and neutral bodies.

Electron, like neutral atoms, has also the mechanical characteristics: mass, energy, momentum and the like. Therefore the most important question of electron theory was the question about the description of these characteristics from the point of view of the theory of electromagnetic field. Therefore enormous efforts were applied by scientists in order to show that all these mechanical characteristics can be explained by electromagnetic theory. In other words it was necessary to express all these characteristics through the characteristics of electromagnetic field.

Remarkable successes were here achieved. The nonquantized nature of theory was their only great drawback. About the significance of electron theory testifies the fact that the majority of its results were used for the development of the quantum theory of elementary particles.

Some of the first, were results obtained by J.J. Thomson (Thomson, 1881). These results were confirmed and developed by other scientists (Lorentz, Heaviside, Hasenoehrl], Larmor, Abraham, Poincare and other). As an introduction we give quotations from the later popular article of J.J. Thomson "***The origin of the mass of the charge corpuscle***" (Thomson, 1907):

"The origin of the mass of the corpuscle is very interesting; for it has been shown that this mass arises entirely from the charge of electricity on the corpuscle. We can see how this comes about in the following way. If we take an uncharged body of mass m *at rest and set it moving with the velocity* υ*, the work we shall have to do on the body is equal to the kinetic energy it has acquired, i.e., to* $m\upsilon^2/2$. *If, however, the body is charged with electricity we will have to do more work to set it moving with the same velocity, for a moving charged body produces magnetic force, it is surrounded by a magnetic field*

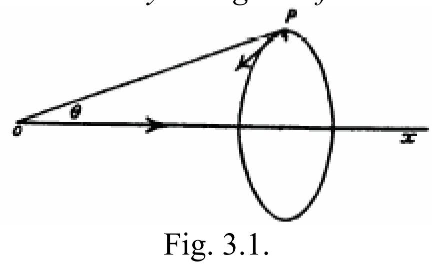


Fig. 3.1.

and this field contains energy; thus when we set the body in motion we have to supply the energy for this magnetic as well as for the kinetic energy of the body. If the charged body is moving along the line OX, the magnetic force at a point P is at right angles to the plane POX

; thus the lines of magnetic forces are circles having OX for their axis. The magnitude of the force at P is equal to $\dfrac{e\upsilon\sin\theta}{OP}$ *where* θ *denotes the angle POX. Now in a magnetic field the energy per unit volume at any place, where the magnetic force is equal to* H *, is* $H^2/8\pi$ *. Thus the energy per unit volume at P arising from the magnetic force produced by the moving charge is* $\dfrac{1}{8\pi}\dfrac{e^2\upsilon^2\sin^2\theta}{(OP)^4}$*, and by taking the sum of the energy throughout the volume surrounding the charge, we find the amount of energy in the magnetic field. If the moving body is a conducting sphere of radius* a*, a simple calculation shows that the energy in the magnetic field is equal to* $\dfrac{1}{3}\dfrac{e^2\upsilon^2}{a}$ *. The energy which has to be supplied to set the sphere in motion is this energy plus the kinetic energy of the sphere, i.e., it is equal to* $\dfrac{1}{2}\left(m+\dfrac{1}{3}\dfrac{e^2}{a}\right)\upsilon^2$

Thus the energy is the same as if it were the kinetic energy of a sphere with a mass $\dfrac{2}{3}\dfrac{e^2}{a}$ *instead of* m*. Thus the apparent mass of the electrified body is not* m *but* $m+\dfrac{2}{3}\dfrac{e^2}{a}$*. The seat of this increase in mass is not in the electrified body itself but in the space around it, just as if the aether in that space were set in motion by the passage through it of the lines of force proceeding from the charged body, and that the increase in the mass of the charged body arose from the mass of the aether set in motion by the lines of electric force. It may make the consideration of this increase in mass clearer if we take a case which is not electrical but in which an increase in the apparent mass occurs from causes which are easily understood. Suppose that we start a sphere of mass* m *with a velocity* υ *in a vacuum, the work which has to be done on the sphere is we* $m\upsilon^2/2$*…*

But since this addition to the mass increases rapidly as the body gets smaller, the question arises, whaether in the case of these charged and exceedingly small corpuscles the electrical mass, as we may call it, may not be quite appreciable in comparison with the other (mechanical) mass. We shall now show that this is the case; indeed for corpuscles there is no other mass : all the mass is electrical.

The method by which this result has been. arrived at is as follows: The distribution of magnetic force near a moving electrified particle depends upon the velocity of the particle, and when the velocity approaches that of light, is of quite a different character from that near a slowly moving particle. Perhaps the clearest way of seeing this is to follow the changes which occur in the distribution of the electric force round a charged body as its velocity is gradually increased."

Foreseeing some questions let us note that all these results were obtained within the framework of electromagnetic theory, which remains the same from the times of J.J. Thomson and H. A. Lorentz till the present time. Moreover, the obtained mathematical "electromagnetic" expressions are the same "relativistic" expressions, which are used today, because the classical electrodynamics is invariant with respect to the Lorentz transformations.

In order to be convinced of this, it is sufficient to compare the content of the articles and books of J.J. Thomson, Lorentz and other authors of that time with the contemporary textbooks on the electrodynamics; see, for example, (Jackson, 1999; Pursell, 1984; and others). In many of these books are presented the results, obtained in the 19th century. Especially recommended is the textbook (Jackson, 1999), and also R. Feynman lectures. In particular, questions about electromagnetic mass briefly, but very deeply examined in the chapter 28 of volume 6, called "Electromagnetic mass" (Feynman et al., 1964).

It does not make any sense to present in detail all these results, since, because of the Internet, the reader can be introduced to them by the ultimate sources. We will here only illustrate the basic achievements of these scientists, among whom Lorentz was rightfully the most important one.

In 19th Century it was shown that:

1) The part of energy and momentum of an electron as a "clot" of electromagnetic field is determined by energy and momentum of its electromagnetic field. In this case the mass is determined through the energy of the field of electron.

(Feynman et al., 1964): "***28-1 The field energy of rest charge***

Suppose we take a simple model of an electron in which al of its charge e is uniformly distributed on the surface of a sphere of radius a. Now let's calculate the energy in the electromagnetic field. The magnitude of the electric field is $E = e/r^2$, and the energy density is

$$u = \frac{1}{8\pi}\vec{E}^2 = \frac{e^2}{64\pi^2 r^4}, \qquad (3.2.1)$$

This is readily integrated. The lower limit is a, and the upper limit is ∞, so

$$\varepsilon = \frac{1}{2}\frac{e^2}{a}, \qquad (3.2.2)$$

28-2 The field momentum of a moving charge

The momentum density is

$$\vec{g} = \frac{1}{4\pi c}\left[\vec{\mathrm{E}} \times \vec{\mathrm{H}}\right], \qquad (3.2.3)$$

The component of $\vec{g}$ in direction of motion we must integrate over all space

$$\vec{p} = \frac{2}{3}\frac{e^2}{ac^2}\vec{\upsilon}, \qquad (3.2.4)$$

(Or taking into account that $\varepsilon = \frac{1}{2}\frac{e^2}{a}$, we obtain $\vec{p} = \frac{4}{3}\frac{\varepsilon}{c^2}\vec{\upsilon}$).

Our calculation was for $\upsilon << c$; what happens if we go to high velocities? .. Lorentz realized that the charged sphere would contract into a ellipsoid at high velocities, and that the fields would change in accordance with formulas, we derived for the relativistic case. If you carry through the integrals for $\vec{p}$ in that case, you find

$$\vec{p} = \frac{2}{3}\frac{e^2}{ac^2}\frac{\vec{\upsilon}}{\sqrt{1-\upsilon^2/c^2}}, \qquad (3.2.5)$$

Inaccuracies in the calculations arose because of the imperfection of the electron model as a statically charged ball. Such an electron cannot be stable. Upon consideration of any forces, which restore stability, the calculations lead to results, which are correct from a contemporary point of view (Fermi, 1922; Wilson, 1936; Kwal, 1949; Rohrlich, 1960).

(Feynman et al., 1964): *"In deriving our equations for energy and momentum, we assumed the conservation laws. We assumed that all forces were taken into account and that any work done and any momentum carried by other "nonelectrical" machinery was included. Now if we have a sphere of charge, the electrical forces are all repulsive and an electron would tend to fly apart. Because the system has unbalanced forces, we can get all kinds of errors in the laws relating energy and momentum. To get a consistent picture, we must imagine that something holds the electron togaether. The charges must be held to the sphere by some kind of rubber bands—something that keeps the charges from flying off. It was first pointed out by Poincare that the rubber bands—or whatever it is that holds the electron togaether—must be included in the energy* *and momentum calculations. For this reason the extra nonelectrical forces are also known by the more elegant name "the Poincare stresses." If the extra forces are included in the calculations, the masses obtained in two ways are changed (in a way that depends on the detailed assumptions). And the results are consistent with relativity; i.e., the mass that comes out from the momentum calculation is the same as the one that comes from the energy calculation. However, both of them contain two contributions: an electromagnetic mass and contribution from the Poincare stresses. Only when the two are added togaether do we get a consistent theory."*

Thus, the problem is how to create the model of electron, in which stresses of Poincare will appear due to the electromagnetic forces of electron itself.

In EM theory for the solution of this problem we have only Lorentz's force, which consists of the electrical part $\rho\vec{\mathrm{E}}$ and the magnetic part $\frac{1}{c}\vec{j}\times\vec{\mathrm{H}}_s$. In the electron theory only the electrical part is examined. Thus, the sequential model of electron must contain a magnetic field that ensures the appearance of magnetic force, which balances the electrical part of Lorentz's force.

2) The self-forces of electron is the reason for the appearance of mass as measures of the inertia of a body

(Jackson, 1999; Jimenez and Campos, 1999): *"The structure and dynamics of the electron derive from the interaction of a charged body with its self-field, and take specific aspects according to the postulated model, either a finite point charge or an extended charged body in interaction with itself.*

This self-interaction gives rise to the radiation reaction problem, that for the point charge appears as self-acceleration or preacceleration, and to an extra inertia, the electromagnetic mass, whose behaviour has been thought to be in conflict with relativity theory ...

2. The extended charge radiation reaction

Historically the first model of the electron to be explored was the extended electron. Lorentz and others conceived the electron as a small spherical charge and the self-force, or radiation reaction, as arising from the retarded interaction of one infinitesimal part of the electron on another. The final result of this approach in the non relativistic limit, for a charge distribution with spherical symmetry, without rotation, and neglecting nonlinear terms, is the series that represents the radiation reaction force $\vec{\mathrm{f}}$ *as*

$$\vec{\mathrm{f}} = -\frac{2e^2}{3c^2}\sum_{n=0}^{\infty}\frac{(-1)^n}{c^n n!}G_n\frac{d^n\vec{\mathrm{a}}(t)}{dt^n}, \qquad (3.2.6)$$

where

$$G_n = \int d^3x d^3x'\rho(x,t)\rho(x',t)|x-x'|^{n-1}, \qquad (3.2.7)$$

The first two terms are

$$\vec{\mathrm{f}}_0 = -\frac{4}{3}\frac{\varepsilon}{c^2}\vec{\mathrm{a}}, \qquad (3.2.8)$$

where ε *is the electrostatic energy of the charge distribution, and*

$$\vec{\mathrm{f}}_1 = -\frac{2e^2}{3c^3}\dot{\vec{\mathrm{a}}}, \qquad (3.2.9)$$

Here $\vec{\mathrm{a}}$ *is the acceleration and* $\dot{\vec{\mathrm{a}}}$ *is the time derivative of acceleration. The other terms are proportional to the size of the charge and therefore go to zero for the point charge. The term proportional to the acceleration may be written as*

$$\vec{\mathrm{f}}_0 = -\frac{4}{3}m\vec{\mathrm{a}}, \qquad (3.2.10)$$

defining $m = \varepsilon / c^2$ *. Here appears the factor 4/3, that supposedly is in conflict with relativity theory. We will argue that the conflict is rather between two different conceptions of a purely electromagnetic electron. The other term, proportional to* $\dot{\vec{a}}$ *and independent of the size of the electron, is usually but not correctly interpreted as a radiation reaction force for a point charge."*

(Feynman et al., 1964): "***28-4 The force of an electron on itself***

We can think of the electron as a charged sphere. When it is at rest, each piece of charge repels electrically each other piece, but the forces all balance in pairs, so that there is no net force. [See Fig. 28-3(a).] However, when the electron is being accelerated, the forces will no longer be in balance because of the fact that the electromagnetic influences take time to go from one piece to another. For instance, the force on the one piece in Fig. 28-3(b) from this piece on the opposite side depends on the position of at an earlier time, as shown. Both the magnitude and direction of the force depend on the motion of the charge. If the charge is accelerating, the forces on various parts of the electron might be as shown in Fig. 28-3(c). When all these forces are added up, they don't cancel out. They would cancel for a uniform velocity, even though it looks at first glance as though the retardation would give an unbalanced force even for a uniform velocity. But it turns out that there is no net force unless the electron is being accelerated. With acceleration, if we look at the forces between the various parts of the electron, action and reaction are not exactly equal, and the electron exerts a force on itself that tries to hold back the acceleration. It holds itself back by its own bootstraps".

3) The mass of electron depends on the speed of the motion of electron. A change in the momentum of an electron is also connected with this.

"In the theory of electron (Bulgakov, 1911) *it is necessary to deny the simple view of the mass as constant, which does not depend on speed, and it is necessary to consider that* m *there is a function of* υ *and, furthermore, value* m *depends on the direction of the acting force.*

Let us assume that the force has the same direction as the momentum (therefore, as speed). Then it is expressed by time derivative dp/dt*. The projection of acceleration in the direction of speed is equal to* $d\upsilon/dt$*; at the same time* $dp/dt = \frac{dp}{d\upsilon}\frac{d\upsilon}{dt}$*. Value* $m_s = dp/d\upsilon$ *has the name of longitudinal mass.*

If the value of momentum does not change, and the only thing that changes is the direction, then it is necessary to examine the geometric increase in the momentum $\Delta p = \alpha p$*, where* α *is the angle, to which the direction* p *was turned. On the other hand, we know that acceleration, perpendicular to the speed, is equal to* υ^2/ρ*, where* ρ *is radius of curvature. The angle* α*, to which the direction of tangent in the time interval* Δt *is turned, is determined by equality* $\alpha = \frac{\upsilon}{\rho}\Delta t$ *(since* $\rho = \lim \frac{\Delta s}{\alpha}$*, where* $\Delta s = \upsilon\Delta t$ *is the arc length).*

The value of force in this case is equal to $\Delta p/\Delta t$*. But* $\Delta p = p\frac{\upsilon}{\rho}\Delta t$*. Consequently, the amount of force is equal to* $p\frac{\upsilon}{\rho}$*; this value is possible to be presented in the form of product* $\frac{p}{\upsilon}\cdot\frac{\upsilon^2}{\rho}$*. Coefficient* p/υ *in the acceleration* υ^2/ρ *has the name of transverse mass* $m_r = p/\upsilon$ *.*

In the simplest case of matterial point, examined in mechanics, the momentum p *is expressed by the product* $m\upsilon$*, where* m *is a constant value. Then* p/υ *is equal to* p/υ *and therefore* $m_s = m_r = m$*.*

This does not take place for the electron: in this case the momentum p *is expressed by a more complicated function of* υ *and longitudinal mass* m_s *is not equal to transverse* m_r *.*

Let us derive the expression of the mass of electron, relying on the law of relativity; taking into account that with $\upsilon = 0$ $m_s = m_r = m_0$ we will obtain for the longitudinal and transverse masses $m_s = \frac{dp}{d\upsilon} = \frac{m_0}{\left(1-\upsilon^2/c^2\right)^{3/2}}$ and $m_r = \frac{p}{\upsilon} = \frac{m_0}{\sqrt{1-\upsilon^2/c^2}}$, respectively. This form have expressions of mass, which are derived from the law of relativity and are in accordance with Lorentz's theory…".

4) Electron as "clot" of field is more deformed, the higher the speed of electron motion is, moreover in this case in longitudinal direction body size is contracted and in the transversal direction it is enlarged.

Let us consider the connection of the shape of the electromagnetic field of electron with the motion of the charged particle (Pamyatnykh, 2001):

"Let us examine the motion of charge (in particular, classical electron), in a certain fixed coordinate system. What does occur in this case regarding the field of electron?

"Let us introduce the vector $\mathbf{R} = (x - \mathbf{V}\cdot t, y, z)$ (Fig. 1),

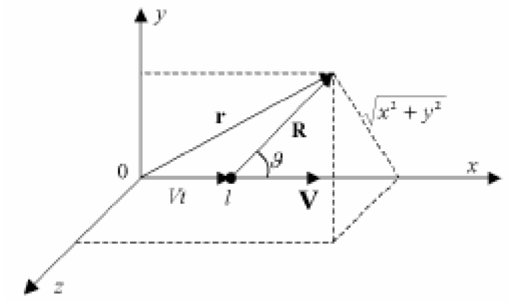


Fig. 3.2

which is directed from the charge to the observation point. Using Lorentz transformation for EM field it is not difficult to show that the strengths of the field of the moving charge (electron) will take the form:

$$\mathbf{E} = \frac{e\mathbf{R}}{R^3}\frac{1-V^2/c^2}{\left(1-(V^2/c^2)\sin^2\vartheta\right)^{3/2}} \qquad \mathbf{H} = \frac{1}{c}[\mathbf{V}\times\mathbf{E}]$$

From here it follows that with low speeds ($|\mathbf{V}| << c$) *the strength of electric field is approximately identical to all directions and is equal to the strength of the field of the rest charge:*

$$\mathbf{E} = \frac{e\mathbf{R}}{R^3}$$

Furthermore, a magnetic field $\mathbf{H} = (1/c)[\mathbf{V}\times\mathbf{E}]$ *also appears.*

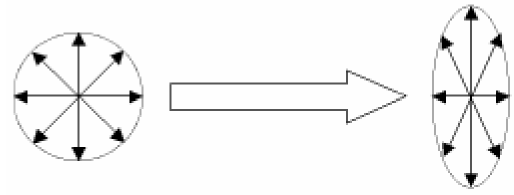
With the high speed motion the value of the field strength depends on direction. In particular, along and against the direction of motion the field is decreased in comparison with the value for the rest charge:

$$E_{\|} = \frac{e}{R^2}\left(1-\frac{V^2}{c^2}\right) < \frac{e}{R^2}$$

On the contrary, in the transversal direction it grows:

$$E_{\perp} = \frac{e}{R^2}\frac{1}{\sqrt{1-(V^2/c^2)}} > \frac{e}{R^2}$$

Thus, the field seems to be "flattened" in the direction of motion (Fig. 2)



a *б*

Fig. 3.3. The "flattening" of the field of the moving charge.
The length of arrows depicts in arbitrary units the value
of electric field strength in a given direction."

5) Velocity mass dependence can be connected with the deformation of electron, if we interpret mass as the resistance to motion of electron in EM aether.
We will use quotation from the same popular article of Thomson (Thomson, 1907):

"*When the body is at rest the electric force is uniformly distributed round the body, i.e., as long as we keep at the same distance from the charged body the electric force remains the same whaether we are to the east, west, north or south of the particle ; the lines of force which come from the body spread out uniformly in all directions. When the body is moving this is no longer the case, for if the body is moving along the horizontal line* (Fig. 3.3)*, the lines of electric force tend to leave the regions, which we shall call the polar regions, and crowd towards a plane drawn at right angles to the horizontal line; the regions in the neighborhood of this plane we shall call the equatorial regions. This crowding of the lines of force is exceedingly slight when the velocity of the body is only a small fraction of that of light, but it becomes very marked when the velocity of the body is nearly equal to that velocity…*

The effect of this crowding of the lines of force towards the equatorial plane is to weaken the magnetic force in the polar and increase it in the equatorial regions. The polar regions are those where the magnetic force was originally weak, the equatorial regions those where it was strong. Thus the effect of the crowding is to increase relatively the strength of the field in the strong parts of the field and to weaken it in the weak parts. This makes the energy in the field greater than if there were no crowding, in which case the energy is $\frac{1}{3}\frac{e^2\upsilon^2}{a}$ *where e is the charge,* υ *the velocity and* a *the radius of the sphere. When we allow for the crowding, the energy will be* $\frac{1}{3}\beta'\frac{e^2\upsilon^2}{a}$*, where* β' *is a quantity which will be equal to unity when* υ *is small compared with* c *the velocity of light, but becomes very large when* υ *approaches* c*. The part of the mass arising from the charge is* $\frac{1}{3}\beta'\frac{e^2\upsilon^2}{a}$*, thus since* β' *depends upon* υ *- the velocity of the particle - the electrical mass will depend upon r, and thus this part of the mass has the peculiarity that it is not constant but depends upon the velocity of the particle. Thus if an appreciable part of the mass of the corpuscle is electrical in origin, the mass of rapidly moving corpuscles will be greater than that of slow ones, while if the mass were in the main mechanical, it would be independent of the velocity".*

6) Lorentz also revealed that the electron has its own "local" time, which depends on the speed of the motion of body relatively to EM aether.

In the electron theory this effect can be interpreted dynamically, as a change in the frequency of wave, which represents the given particle during its motion through EM aether. In framework of STR this effect is interpreted not as local time, but as the kinematics effect of time dilation due to relative motion of bodies.

7) On the basis of Maxwell's equations Lorentz and Larmor derived the Lorentz transformations.

(Feynman et al., 1964):

"21-6 *The potentials for a charge moving with constant velocity; the Lorentz formula*

We want next to use the Lienard-Wiechert potentials for a special case — to find the fields of a charge moving with uniform velocity in a straight line. We (can) do it, using the principle of relativity. We already know what the potentials are when we are standing in the rest frame of a charge. When the charge is moving, we can figure everything out by a relativistic transformation *from one system to the other. But relativity had its origin in the theory of electricity and magnetism. The formulas of the Lorentz transformation… were discoveries made by Lorentz when he was studying the equations of electricity and magnetism. So that you can appreciate where things have come from, we would like to show that the Maxwell equations do lead to the Lorentz transformation. We begin by calculating the potentials of a charge moving with uniform velocity, directly from the electrodynamics of Maxwell's equations. We have shown that Maxwell's equations lead to the potentials for a moving charge that we got in the last section. So when we use these potentials, we are using Maxwell's theory...*

…We get for (scalar potential) ϕ

$$\phi(x,y,z,t)=\frac{q}{\sqrt{(x-\upsilon t)^2+\left(1-\upsilon^2/c^2\right)\left(y^2+z^2\right)}}, \qquad (3.2.11)$$

This equation is more understandable if we rewrite it as

$$\phi(x,y,z,t)=\frac{q}{\sqrt{(x-\upsilon t)^2}}\frac{1}{\left[\left(\frac{(x-\upsilon t)}{\sqrt{1-\upsilon^2/c^2}}\right)^2+y^2+z^2\right]}, \quad (3.2.12)$$

The vector potential $\vec{A}$ *is the same expression with an additional factor of* υ/c^2

$$\vec{A}=\frac{\vec{\upsilon}}{c^2}\phi, \qquad (3.2.13)$$

In Eq. (3.2.12) *you can clearly see the beginning of the Lorentz transformation. If the charge were at the origin in its own rest frame, its potential would be*

$$\phi(x,y,z)=\frac{q}{\left[x^2+y^2+z^2\right]^{1/2}}, \qquad (3.2.14)$$

We are seeing it in a moving coordinate system, and it appears that the coordinates should be transformed by

$$\begin{aligned} x &\to \frac{(x-\upsilon t)}{\sqrt{1-\upsilon^2/c^2}} \\ y &\to y \\ z &\to z \end{aligned}, \qquad (3.2.15)$$

That is just the Lorentz transformation, and what we have done is essentially the way Lorentz discovered it.

8) The theoretical results of electron theory coincided with the results of the experiments, set for the purpose of their checking (experiment of Michaelson- Morley and, etc).

To explain the negative result of the Michelson–Morley experiment the contraction hypothesis was proposed by George Francis FitzGerald and independently proposed and extended by Hendrik Lorentz. (Lorentz, 1916):

"§168. *In order to explain this absence of any effect of the earth's translation, I have ventured the hypothesis, which has also been proposed by FitzGerald, that the dimensions of a solid body undergo slight changes, of the order* $\frac{\upsilon^2}{c^2}$, *when it moves through the aether. If we assume that the lengths of two lines* L_1 *and* L_2 *in a ponderable body, the one parallel and the other perpendicular to the translation, which would be equal to each other if the body were at rest, are to each other in the ratio during the motion,*

$$\frac{L_2}{L_1} = 1 + \frac{\upsilon^2}{2c^2}, \qquad (3.2.16)$$

the negative result of the experiments is easily accounted for…

The hypothesis certainly looks rather startling at first sight, but we can scarcely escape from it, so long as we persist in regarding the aether as immovable. We may, I think, even go so far as to say that, on this assumption, Michelson's experiment proves the changes of dimensions in question…

§172. *We can understand the possibility of the assumed change of dimensions, if we keep in mind that the form of a solid body depends on the forces between its molecules, and that, in all probability, these forces are propagated by the intervening aether in a way more or less resembling that in which electromagnetic actions are transmitted through this medium. From this point of view it is natural to suppose that, just like the electromagnetic forces, the molecular attractions and repulsions are somewhat modified by a translation imparted to the body, and this may very well result in a change of its dimensions."*

9) Since, according to Lorentz's hypothesis, all matterial bodies in the Universe consist of the electromagnetic field, they undergo all effects, which are enumerated above for the electron.

Let us note also that the difficulties of electron theory and inaccuracy in the expressions, obtained in the 19th century, proved to be essentially connected with the imperfection (simplicity) of "ball" model of electron as elementary particle. Unfortunately, there were no attempts to improve theory, taking into account all this knowledge, which was obtained from the end of the 19th century up to now.

Results enumerated above were rediscovered and refined by A. Einstein within the framework the special theory of relativity (STR). (see sources: **Relativity and Electrodynamics of Moving Bodies**. http://en.wikisource.org/wiki/Wikisource:Relativity)

3.0. Kinematics non-electromagnetic theory of matter – specially theory of relativity of Einstein

The special theory of relativity (STR), which appeared in the beginning of the 20th century, is not itself a theory of matter. It is a theory of invariance of the laws of physics relative to the specific transformations. However, the requirement of invariance, which STR imposes on the laws of physics, leads to the reformation of all laws of nature. In this sense STR generates the new theory of matter, results of which are equivalent to the electromagnetic theory of matter.

STR is very simple: it contains two postulates: principle of relativity and postulate of constancy of light speed. The content of postulates of STR is in no way connected with presence or absence of aether or electromagnetic field. These postulates lead directly to the Lorentz transformations. This is sufficient to predict all effects, discovered within the framework of electron theory.

Some scientists and the majority of popularizers asserted on this base that the electron theory of Lorentz was false, since it relies on aether and on the special assumptions.

After being introduced to the work of Einstein, it is possible to ascertain easily that Einstein himself never allowed similar assertions. In his articles there are assertions that within the framework of STR aether is not necessary. There is also an assertion that in nature it is not possible to assign absolute frame of reference. Both assertions are completely correct, but they (for different reasons) do not refute the Lorentz - Larmor theory.

In the theory of Lorentz - Larmor the derivation of the Lorentz transformations is more complex, since the theory uses a more complex system of postulates, and the explanation of effects is here connected with the structure of matterial bodies and with their interaction with EM aether. During the creation of this theory this was its weak place, since there were no sufficient experimental results, which confirm the theory.

So, in the 19th century there were no proofs of the basic assumption (hypothesis), which lies in the basis of electron theory, that the entire matter in nature "consists" of electromagnetic field, and about the fact that "molecular forces are reduced to electrical". The substantiation of these hypotheses required much time and only now we can assert with good reason that they are correct.

The question arises: what connection does exist between STR and electron theory? This connection is revealed, when we attempt to base Einstein's postulates.

Historically Einstein came to the law of relativity on the basis of criticism of the absoluteness of space and time, which was developed by Ernst Mach, and also on the basis of the work of Poincare, who was the first who formulated the relativity principle (http://en.wikipedia.org/wiki/Principle_of_relativity):

"Joseph Larmor and Hendrik Lorentz discovered that Maxwell's equations, the cornerstone of electromagnetism, were invariant only by a certain change of time and length units…

In their 1905 papers on electrodynamics, Henri Poincaré and Albert Einstein explained that with the Lorentz transformations the relativity principle holds perfectly. Einstein elevated the (special) principle of relativity to a postulate of the theory and derived the Lorentz transformations from this principle combined with the principle of the independence of the speed of light (in vacuum) from the motion of the source. These two principles were reconciled with each other (in Einstein's treatment, though not in Poincaré's) by a re-examination of the fundamental meanings of space and time intervals".

It is not difficult to see that the law of relativity occurs due to the fulfillment of the effects of a change in the sizes and own time of bodies, which move relatively to ether. In other words, the substantiation of STR principles lies in the electronic theory of Lorentz and others.

Another question concerns the need for principles of STR in nature. It is possible to see that in the case of the nonfulfillment of these principles (or else: if the effects of a change in the sizes and time are absent), then in each inertially moving system the laws of nature must differ.

As we noted in previous paper (Kyriakos, 2010b), the selection of the system of postulates of any theory is ambiguous, but this does not witness the inaccuracy of one or the other theory, if they lead to the same results (Lorentz, 1916):

"§194. *I cannot speak here of the many highly interesting applications which Einstein has made of this principle. His results concerning electromagnetic and optical phenomena… agree in the main with those which we have obtained in the preceding pages; the chief difference being that Einstein simply postulates what we have deduced, with some difficulty and not altogaether satisfactorily, from the fundamental equations of the electromagnetic field. By doing so, he may certainly take credit for making us see in the negative result of experiments like those of Michelson, Rayleigh and Brace, not a fortuitous compensation of opposing effects, but the manifestation of a general and fundamental principle."*

Thus the contradictions between the electromagnetic theory of matter of Lorentz and STR of Einstein do not exist. In STR the EM aether is seemingly one of the inertial reference systems, which cannot be chosen with experiments, i.e., it can be considered as an absolute frame of reference.

A. Einstein (Einstein, 1920) in his speech "Aether and the theory of relativity" pronounced on May 5, 1920 at the Leyden university, emphasized that **at this prerequisite** the existence of electromagnetic aether does not contradict the special theory of relativity .

"The next position which it was possible to take up in face of this state of things appeared to be the following. The aether does not exist at all….

More careful reflection teaches us, however, that the special theory of relativity does not compel us to deny aether*. We may assume the existence of an aether; only we must give up ascribing a definite state of motion to it…*

The special theory of relativity forbids us to assume the aether to consist of particles observable through time, but the hypothesis of aether in itself is not in conflict with the special *theory of relativity. Only we must be on our guard against ascribing a state of motion to the aether.*

The electromagnetic fields appear as ultimate, irreducible realities, and at first it seems superfluous to postulate a homogeneous, isotropic aether-medium, and to envisage electromagnetic fields as states of this medium.

But on the other hand there is a weighty argument to be adduced in favour of the aether hypothesis. To deny the aether is ultimately to assume that empty space has no physical qualities whatever. The fundamental facts of mechanics do not harmonize with this view…

According to our present conceptions the elementary particles of matter are also, in their essence, nothing else than condensations of the electromagnetic field…»

The absence of contradictions between these two theories (the Lorentz electron theory and STR of Einstein)was already undestood by the contemporaries of Einstein. This is quote from article of Ehrenfest - friend of Einstein (Ehrenfest, 1913):

"*Einstein's theory, denying aether, requires the same as the aether theory of Lorentz. On this base the observer must, according to Einstein's theory, observe on the moving measuring bar, clock et cetera, the same reductions, time difference et cetera, as according to Lorentz's theory. Let us note in this case that such experimentum crucis, which would solve the dispute in favor of one or the other theory, is principally impossible*."

Therefore for obtaining the mathematical results we can use both the approaches of Lorentz and of Einstein.

4.0. Electromagnetic wave theory of matter

In the history of physics a theory under this name is absent. But a number of meaningful results, obtained even in the 19th century, makes it possible to choose this approach as electromagnetic wave theory of matter.

Wave approach to the organization of matter is much closer to the contemporary field and elementary particles theory, than approaches of electron theory of Lorentz and STR of Einstein, mentioned above. As is known, the contemporary theory of elementary particles (Standard Model) is a wave theory. This means that all elementary particles are wave fields and are described mathematically by different wave equations.

In the Maxwell-Lorentz electromagnetic theory the only existing waves are the electromagnetic waves. At the beginning of the 20th century it was revealed that these waves are quantized and consist of particles - the quanta of EM field, i.e. photons; moreover, photons are mass-free particles. Thus, on the basis of the contemporary ideas, the only possibility of the generation of massive particles in the electromagnetic theory is some transformation of photons, as a result of which special massive electromagnetic waves-particles must appear (this approach is close to Higgs's mechanism, see below).

Here we will recall some results of the 19th century and estimate them from the results of contemporary theory point of view of the. Because of the dualism wave-particle, we will further examine photon as electromagnetic wave and particle simultaneously.

4.1. Energy and momentum of electromagnetic wave (photon)

The fact that EM wave has an energy and a momentum, it was discovered already into the 19th century. The EM wave presses the metallic wall, and also it can revolve a light rotator. By this we can assume that EM wave (photon) has a mass.

For the time average of the pressure of the train of EM waves with area s and length l, the following expression (Becker, 1982) is obtained: $\mathrm{P} = \frac{1}{8\pi}\left(\vec{\mathrm{E}}^2 + \vec{\mathrm{H}}^2\right) = u$, where u is the energy density of EM wave. The important dependence between energy and momentum of wave is already included in this equation. The total momentum, transmitted from EM train to wall will be equal to: $p = u \cdot s \cdot t$, where $t = l/c$ is the time of action of train. Thus, the transmitted momentum is equal to: $p = u \cdot s \cdot l / c$. Since the numerator $u \cdot s \cdot l = \varepsilon$ is the energy of train, we obtain $p = \varepsilon / c$. If we assign to EM wave a mass m', then it is possible to consider that $p = m'c$. In that case we obtain $m' = \varepsilon / c^2$ - the known relationship of Einstein.

Nevertheless, later it was proven that photon is a mass-free particle in the sense that its rest mass is equal to zero. But if we interpret the collision of EM wave with the wall as the stoppage of EM wave, then it is possible to say that the "stopped" photon acquires mass m'.

This result led, evidently, to a study of other methods of the "stoppage" of EM waves for the purpose of understanding the origin of mechanical mass of the material bodies **(The authors, 2005):**

"15. ***The Mass of a Box Full of Light***

The experimental confirmation of the pressure of light in 1901 led to new theoretical work. In 1904, Max Abraham computed the pressure produced by radiation upon a moving surface, when the beam of light reaches the surface in a mirror in any angle. Starting from Abraham's results, Friedrich Hasenoehrl (1874-1916) *studied the dynamics of a box full of radiation.*

Imagine a cubic box with perfectly reflecting internal surfaces, full of light. When the box is at rest, the radiation produces equal forces upon all those surfaces, Nov. suppose that the box is accelerated, in such a way that one of its surfaces moves in the x direction. It is possible to prove that, when the radiation inside the box strikes this surface, the pressure will be smaller, and when it strikes the opposite surface, the pressure will be greater, than in the case when the box is at rest (or in uniform motion). Therefore, the radiation inside the box will produce a resultant force against the motion of the box. So, to accelerate a box full of light requires a greater force than to accelerate the same box without light. In other words, the radiation increases the inertia of the box. In the case when the radiation inside the box is isotropic, there is a very simple relation between its total energy E and its contribution m to the inertia of the box (Hasenoehrl, 1904; 1905):

$$m = \frac{4\varepsilon}{3c^2}, \qquad (3.4.1)$$

Note that here, as in the theory of the electron, there appears a numerical factor 4/3. This is not a mistake. The relation between those equations and the famous $\varepsilon = mc^2$ *will be made clear later* (Fadner, 1988).

Hasenoehrl also computed the change of the radiation energy as the box was accelerated. He proved that the total radiation energy would be a function of the speed of the box. Therefore, when the box is accelerated, part of the work done by the external forces is transformed into the extra radiation energy. Since the inertia of the radiation is proportional to its energy, and since this energy increases with the speed of the box,, the inertia of the box will increase with its speed. Of course, if the internal temperature of the box were increased, the radiation energy would augment, and the inertia of the box would also increase. Therefore, Hasenoehrl stated that the mass of a body depends on its kinetic energy and temperature".

Let us conditionally name the totality of EM waves in a box as 'EM-particle'. From the foresaid above it is obvious that the mass of 'EM-particle', calculated according to Lorentz's theory, will also have a coefficient of 4/3 like the mass of classical electron. Obviously, upon consideration of the stresses of Poincare we will obtain the coefficient one. The stresses of Poincare were introduced for the stabilization of the electrostatic field of classical electron. In the case in question the stability exists due to interaction of EM wave with the walls of the box. These interactions play in this case the role of the stresses of Poincare, which ensure the stability of 'EM particle'. Naturally, if we take into account the presence of these stresses, we will also obtain the coefficient one (of course this result will also appear, if we use Einstein's approach).

With the perpendicular fall of EM waves on the walls of the box the stress is pressure. With inclined fall the components of stress will formally consist both of pressures and tangent stresses (as a result of the resolution of momentum on perpendicular and tangential components). The stress tensor of Maxwell (and generally, continuous medium tensor) consists precisely of such components. In this example the stresses are not mechanical: EM waves interact with the electrons of the wall atoms by means of EM Lorentz's forces. Nevertheless, these stresses are external with respect to EM waves in the box, i.e., they are not organized by the EM waves themselves.

The question arises: are such conditions possible, when EM wave can ensure themselves the stability of 'EM-particle' without the presence of external actions? In this case we will actually have a massive "particle", generated by EM waves. Obviously, this case can be realized only as a result of the self-interaction of parts of EM waves. This means that the equation of EM wave-particle must be nonlinear.

We can improve our model for the purpose to do approach the quantum field theory. Let us select a box with mirror walls of the size of the order of a wavelength λ. If we consider resonance conditions, the box itself will select the appropriate wavelength. This corresponds to the case when we placed into this box one photon. In the case of quantum theory we can speak about the photon in a cell of phase size. If we ignore the presence of walls, it is possible to consider photon in the box as particle. This particle possesses spin one and mass, determined by its energy $m' = \varepsilon / c^2 = \hbar / \lambda c$. In other words, we have a model of the neutral massive boson, similar to intermediate boson.

The mathematical description of this model in the classical case can be given on the basis of the theory of waveguides and resonators (Crawford Jr., 1968; Broglie, 1941). As is known, the motion of waves is determined by the dispersion equation (or by another dispersion relationship).

Dispersion equation is the relationship, which connects angular frequencies ω and wave vectors k of natural harmonic waves (normal waves) in linear uniform systems: continuous media, waveguides, transmission lines and others. Dispersion equation is written in the form $\omega = \omega(k)$.

Dispersion equations are the consequence of the dynamic (in the general case integrodifferential) equations of motion and of boundary conditions. And also, vice versa, on the base of the form of dispersion equation the dynamic equations of processes can be restored with the replacement:

$$i\omega \rightarrow \frac{\partial}{\partial t},\ ik_x \rightarrow -\frac{\partial}{\partial x},\ \frac{1}{i\omega} \rightarrow \int (...)dt,\ \frac{1}{ik_x} \rightarrow \int (...)dx, \quad (3.4.2)$$

It is easy to obtain the dispersion equation for the infinite wave without any limiting conditions $\vec{\Phi} = \vec{\Phi}_o e^{-i(\omega t - ky)}$, using the homogeneous wave equation:

$$\left(\frac{\partial^2}{\partial t^2} - c^2 \vec{\nabla}^2 \right) \vec{\Phi} = 0, \quad (3.4.3)$$

where $\vec{\Phi}$ are in our case any vector components of electrical and magnetic field. Putting this solution, we obtain $\omega^2 - \upsilon^2 k^2 = 0$ or $\omega = \upsilon \cdot k$.

In the case of the presence of limitations, superimposed on the wave by medium or by it self, the equation becomes heterogeneous:

$$\left(\frac{\partial^2}{\partial t^2} - c^2 \vec{\nabla}^2 \right) \vec{\Phi} = \vec{\Phi}_0, \quad (3.4.4)$$

where $\vec{\Phi}_0$ is certain function of the electromagnetic fields. In this case dispersion relationship becomes more complex: new terms are introduced and its linearity is disrupted.

The same relationship dispersion equation:

$$\omega^2 = \omega_0^2 + \upsilon^2 k^2, \quad (3.4.5)$$

can correspond to: 1) EM waves in the isotropic plasma; 2) plasma waves; 3) waves in the waveguides; 4) waves in the acoustic waveguides; 5) elementary particle in relativistic wave mechanics ($\upsilon = c$, $\omega_0 = m_0 c^2 / \hbar$, m_0 is rest mass).

In the latter case the discussion deals with de Broglie wave dispersion relation. Energy, momentum, and mass of particles are connected through the relativistic relation

$$\varepsilon^2 = \left(m_0 c^2\right)^2 + (pc)^2, \qquad (3.4.6)$$

Elementary particles, atomic nuclei, atoms, and even molecules behave in some context as matter waves. According to the de Broglie relations, their kinetic energy ε can be expressed as a frequency ω: $\varepsilon = \hbar\omega$, and their momentum p as a wave number k: $p = \hbar k$.

(Broglie, 1941): *"The relationships, obtained for EM wave in a waveguides or in a box, are completely analogous to those, which exist in wave mechanics, in which the rectilinear and uniform particle motion with the rest mass m_0 depicts in the form of propagation of plane simple harmonic wave $\psi = \psi_0 e^{i(\omega t - kr)}$.*

As we noted, $\omega = ck$ corresponds to the propagation of EM wave in the vacuum. But if EM wave is in the waveguide, then between ω and k we have the relationship (3.4.6)*, where ω_0 is different from zero and it is equal to one of its eigenvalues, which correspond to the form of the waveguide in question. From the point of view of wave mechanics everything happens as if the photon had its own mass, determined by the form of waveguide and by the eigenvalue $\omega_{0i} = m_{0i}/\hbar$. Thus, it is possible to say that in this waveguide the photon can possess a series of possible own masses".*

From a contemporary point of view we can interpret the appearance of photon mass as follows. A photon, until its entry into a waveguide or resonator, obeys to the linear equation

$$\left(\Delta - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\right)\vec{\Phi} \equiv \sum_\nu \frac{\partial^2}{\partial x_\nu^2}\vec{\Phi} \equiv \partial_\nu \partial^\nu \vec{\Phi} = 0, \qquad (3.4.7)$$

Lagrangian of which

$$L = \frac{1}{2}\left\{\left(\frac{\partial\vec{\Phi}}{\partial t}\right)^2 - c^2\left(\vec{\nabla}\psi\right)^2\right\} \equiv \frac{1}{2}c^2 \sum_\nu \left(\frac{\partial\vec{\Phi}}{\partial x_\nu}\right)^2 \equiv \partial_\nu \vec{\Phi}\partial^\nu \vec{\Phi}, (3.4.8)$$

describes the mass-free field. After entry to a box the photon experiences a certain spontaneous transformation and becomes massive particle. Each component of the field of this massive particle obeys to Klein-Gordon equation (Wentzel, 2003).

The Klein-Gordon wave equation

$$\left(\Delta - \frac{1}{c^2}\frac{\partial^2}{\partial t^2} - m^2\right)\vec{\Phi} \equiv \left(\sum_\nu \frac{\partial^2}{\partial x_\nu^2} - m^2\right)\vec{\Phi} \equiv \left(\partial_\nu\partial^\nu - m^2\right)\vec{\Phi} = 0, \ (3.4.9)$$

This is achieved by choosing the following, evidently Lorentz-invariant Lagrangian:

$$L = \frac{1}{2}\left\{\left(\frac{\partial\vec{\Phi}}{\partial t}\right)^2 - c^2\left(\vec{\nabla}\vec{\Phi}\right)^2 - c^2 m^2 \vec{\Phi}^2\right\} \equiv -\frac{1}{2}c^2\left\{\sum_\nu \left(\frac{\partial\vec{\Phi}}{\partial x_\nu}\right)^2 + m^2\vec{\Phi}\vec{\Phi}^+\right\} \equiv \partial_\nu\vec{\Phi}\partial^\nu\vec{\Phi} - c^2 m^2 \vec{\Phi}^2$$

(3.4.10)

This transformation has some common features with Higgs's mechanism, to the examination of which we will pass.

5.0. From electromagnetic aether to the physical vacuum and from the latter to Higgs's vacuum

5.1. Idea of electromagnetic aether

From the times of Faraday and Maxwell the existence of the equations, which describe the electromagnetic field, is the consequence of the existence of a certain medium - electromagnetic aether (EME), motions of which are described by Maxwell's equations without charges and currents (Lorentz, 1933; Bateman, 1915; Richardson, 1916; etc).

(Bateman, 1915): "***Ch. I. 1. The fundamental equations for free aether.*** *In Maxwell's electromagnetic theory the state of the aaether in the vicinity of a point (x, y, z) at time t is specified by means of two vectors E and H which satisfy the circuital relations*

$$rot\vec{H} = \frac{1}{c}\frac{\partial\vec{E}}{\partial t}, \; rot\vec{E} = -\frac{1}{c}\frac{\partial\vec{H}}{\partial t} \; , \qquad (3.5.1)$$

and the solenoidal or sourceless conditions

$$div\vec{E} = 0, \; div\vec{H} = 0, \qquad (3.5.1)$$

As we know, for such – electromagnetic - aether the Lorentz transformations are valid. The question about the mathematical description of aether as a certain continuous medium, came up from the early times. But it is obvious that the use of Maxwell's electrodynamics for the derivation of equations of EMA is illogical. This would indicate the change of places of cause and effect. In the sequential theory we must first describe the medium – i.e., EME, and on this base derive Maxwell's equations as the equations of its motion. Physicists of classical epoch attempted to do specifically this during the 19th century.

But according to Maxwell's equations the structure of EM field is very complex: here exist field rotations, the mutual perpendicularity of the vectors of field, different polarization and many others. The medium, which must generate these effects, does not exist among known classical continuous media (gas, liquid, plasma, electrolyte, crystal and the like). Therefore the invention of such medium, in which Maxwell's equations can "exist", was not successful.

Most suitable proved to be the hypothetical medium with rotatory elasticity, proposed by McCullagh and then modeled by William Thomson (Lord Kelvin). The equations of motion of this medium were identical to Maxwell's equations. But investigations in this direction were stopped after the appearance of QM. Only in the middle of 20th century the theory of a medium arose, which replaced aether, as the basis of existence of elementary particles; this was the theory of physical vacuum.

The history of the development of ideas in this area is presented in many courses of the physics history (Whittaker, 1910; Kudryavtsev, 1971; Spasskiy, 1977), and we will not stop on this question. Let us give only several quotations of the last survey work in this area of Oliver Lodge (Lodge, 1909), which sum up the results of the electromagnetic theory of matter.

"The problem of the constitution of the Aether, and of the way in which portions of it are modified to form the atoms or other constituent units of ordinary matter, has not yet been solved…

Meanwhile there are few physicists who will dissent from Clerk-Maxwel's penultimate sentence in the article "Aether," of which the beginning has already been quoted: "Whatever difficulties we may have in forming a consistent idea of the constitution of the aether, there can be no doubt that the interplanetary and interstellar spaces are not empty, but are occupied by a material substance or body, which is certainly the largest, and probably the most uniform body of which we have any knowledge."…

But now comes the question, how is it possible for matter to be composed of aether? How is it possible for a solid to be made out of fluid? A solid possesses the properties of rigidity, impenetrability, elasticity, and such like; how can these be imitated by a perfect fluid such as the aether must be?

The answer is: they can be imitated by a fluid in motion; a statement which we make with confidence as the result of a great part of Lord Kelvin's work…

A vortex-ring, ejected from an elliptical orifice, oscillates about the stable circular form, as an india-rubber ring would do; thus furnishing a beautiful example of kinetic elasticity, and showing us clearly a fluid displaying some of the properties of a solid…

A still further example is Lord Kelvin's model of a spring balance, made of nothing but rigid bodies in spinning motion. This arrangement utilises the processional movement of balanced gyrostats — concealed in a case and supporting a book — to imitate the behaviour of a spiral spring, if it were used to support the same book…

If the aether can be set spinning, therefore, we may have some hope of making it imitate the properties of matter, or even of constructing matter by its aid.

The estimates of this book, and of Modern Views of Electricity, are that the aether of space is a continuous, incompressible, stationary fundamental substance…

The aether inside matter is just as dense as the aether outside, and no denser. A material unit — say, an electron — is only a peculiarity or singularity of some kind in the aether itself, which is of perfectly uniform density everywhere. What we "sense" as matter is an aggregate or grouping of an enormous number of such units.

The elasticity of the aether,… if this is due to intrinsic turbulence, the speed of the whirling or rotational elasticity must be of the same order as the velocity of light…

The three vectors at right angles to each other, which may be labeled Current, Magnetism and Motion respectively or more generally $\vec{E}$, $\vec{H}$ *and* $\vec{\upsilon}$, *represent the quite fundamental relation between aether and matter, and constitute the link between Electricity, Magnetism and Mechanics. Where any two of these are present, the third is necessary consequence*".

5.2. Representation of classical EM field in the form of oscillators (canonical representation of classical EM field according to Hamilton)

Maybe it is strange, but the push to mathematical analysis of the structure of electromagnetic aether (EMA) was given by the investigation of the structure of "quantum aether" - electromagnetic physical vacuum (Dirac, 1927; Fermi, 1932; and others). As one would expect, these representations are not based on a strict axiomatics, but they contain a number of hypotheses. It is possible to say that these researches are not the construction of the theory of aether, but the "reconstruction" of its model on the basis of the equations of EM waves, which are propagated in it.

(Feynman, 1948**):** *In classical electrodynamics the fields describing, for instance, the interaction of two particles can he represented as a set of oscillators. The equations of motion of these oscillators may be solved and the oscillators essentially eliminated (Lienard and Wiechert potentials).*

(Thus, the discrete continuum of particles-oscillators is changed here by the continuum of field, expressed through the potentials; but obviously, it is possible to express it also through the field strengths).

The interactions which result involve relationships of the motion of one particle at one time, and of the other particle at another time. In quantum electrodynamics the field is again represented as a set of oscillators. But the motion of the oscillators cannot be worked out and the oscillators eliminated.

Let us present without details the principles of the theory of physical vacuum in the quantum field theory (Landau and Lifshitz, 1975; Levich et al., 1973; Martynenko, 2001). The theory consists of two parts: 1) the theory of electromagnetic aether, and 2) the theory of the quantization of EM aether, which leads to the physical vacuum. Let us examine them in this sequence.

"*Let us examine electromagnetic (EM) field in space* τ *without charges. The energy of EM field in this space is:*

$$\varepsilon = \frac{1}{8\pi}\int_{\tau}\left(\vec{E}^2 + \vec{H}^2\right)d\tau, \qquad (3.5.1)$$

where the strengths of EM field $\vec{E}, \vec{H}$ *can be expressed through the vector potential:*

$$\vec{E} = -\frac{1}{c}\frac{\partial\ \vec{A}}{\partial\ t} = -\frac{1}{c}\dot{\vec{A}}_{\vec{k}}, \quad \vec{H} = rot\ \vec{A}, \qquad (3.5.2)$$

Expanding the vector potential on the plane waves

$$\vec{A} = \sum_k \left(\vec{A}_{\vec{k}} e^{i\vec{k}\vec{r}} + \vec{A}_{\vec{k}}^{\ *} e^{i\vec{k}\vec{r}} \right), \qquad (3.5.3)$$

we obtain for the energy of EM field the following expression:

$$\varepsilon = \sum_k \left(\frac{\left|\dot{\vec{A}}_{\vec{k}}\right|^2}{8\pi\ c^2} + \frac{\vec{k}^2 \left|\vec{A}_{\vec{k}}\right|^2}{8\pi} \right), \qquad (3.5.4)$$

Thus, the total energy of the EM field can be represented as the sum of energies of harmonic oscillators. Value $\vec{A}_{\vec{k}}$ plays here the role of coordinate $q_{\vec{k}}$; $\dot{\vec{A}}_{\vec{k}}$ - the role of speed $\upsilon_{\vec{k}}$; $1/4\pi c^2$ - of mass of harmonic oscillator; $\omega_{\vec{k}} = \sqrt{\beta/m} = ck$ are the frequencies of oscillators (here $\beta = k^2/4\pi$). In this case the product of "mass" to "speed" corresponds to the momentum of oscillator $p_{\vec{k}}$. In this sense, the first term in (3.5.4) is kinetic electromagnetic energy, and the second – potential energy.

Thus, the EM field in space without charges can be considered as the sum of independent harmonic oscillators with all possible values of wave vector $\vec{k}$.

In these designations (Levich et al., 1973) the energy of field can be written down in the form

$$\varepsilon = \frac{1}{2} \sum_k \left(p_{\vec{k}}^2 + \omega_{\vec{k}}^2 q_{\vec{k}}^2 \right), \qquad (3.5.5)$$

It is interesting to note that the medium, proposed by lord Kelvin and others as EMA (see above the quote from book of Lodge (Lodge, 1909)), also consists of free oscillators: the rotating elements of this medium, which can be considered as mechanical, can be described by harmonics $e^{i\vec{k}\vec{r}}$.

Let us note, that everything that we presented above is the classical theory of electromagnetic field.

. Thus (Levich et al., 1973), the electromagnetic field in its final volume is formally equivalent to mechanical system with an infinitely large, but enumberable number of degrees of freedom, i.e., the collection of the field oscillators. In this case the equations of field are equivalent to Hamiltonian equations of motion of the field oscillators. Frequently the Hamilton function of the equivalent system of oscillators is simply named as Hamiltonian function of field, and the expansion of vector (3.3) – as field expansion to the oscillators.

Let us focus on the fact that at present the passage to the canonical form is most frequently accomplished with the use of potentials. Because of the important role of gauge transformations in contemporary physics, the form of the wave function in the form of potential was affirmed in the field theory as preferred. In reality the same transformations can be produced, using the field strengths (for example, see (Goldstein and Zernov, 1971))

How should the possibility of the representation of the EM field be interpreted in the form of oscillators? Obviously, it is possible to consider that the field expansion to the oscillators has a nature of computational method, since within the framework of classical electrodynamics the oscillators of field cannot be connected with any particles, because do not take into account the quantization of field. The importance of this decomposition was revealed in the quantum theory of electromagnetic field. This makes it possible to assert that quantized aether of classical electrodynamics is the physical vacuum of the quantum field theory.

5.3. Quantization of the electromagnetic field. Quantum field theory

At the basis of the quantum theory of EM field lies (Levich et al., 1973) "*the assumption that this analogy is possible to be given the direct physical content*". Specifically, it is assumed that the real EM field presents the quantum system, which is obeyed to the usual laws of quantum mechanics.

EM aether is electromagnetic field in the lower energy level. Therefore it can be quantized just as the electromagnetic field.

For the passage from the classical description to the quantum it is necessary to replace classical characteristics with quantum operators.

The quantum operator Hamilton is obtained from (3.5.5) by the usual replacement of the mechanical values of generalized coordinates and momentums by the corresponding quantum operators $\hat{p}_\lambda$ and $\hat{q}_\lambda$, which must obey to the known commutation relationships:

$$\begin{aligned} &\hat{q}_\mu \hat{p}_\lambda - \hat{p}_\lambda \hat{q}_\mu = i\hbar\delta_{\lambda\mu} \\ &\hat{q}_\mu \hat{q}_\lambda - \hat{q}_\lambda \hat{q}_\mu = 0, \hat{p}_\mu \hat{p}_\lambda - \hat{p}_\lambda \hat{p}_\mu = 0 \end{aligned}, \qquad (3.5.6)$$

This representation is possible according to the fact (Gottfried and Weisskopf, 1984), that the electrical $\vec{E}$ and magnetic $\vec{H}$ fields obey to commutation relationships of the same type as operators $\hat{q}$ and $\hat{p}$. Actually (Shirkov and Belokurov, 1991), *"An important role in understanding of the physical sense of the quantized field of emission played the work of N. Bohr and L. Rosenfeld* (Bohr and Rosenfeld, 1933; Engl. trans.: 1979), *which showed that between the strengths of electrical and magnetic field exist the uncertainty principles, similar to the Heisenberg relationships between the coordinate and the momentum. Therefore, for example, it is not possible simultaneously to measure accurately the x component of the strength of electric field and y - and z -components of the strength of magnetic field*".

Let us (Levich et al., 1973) apply now the laws of quantum mechanics to the system in question. In quantum mechanics the oscillator can be found only in the states with discrete values of the energy:

$$\varepsilon = \sum_k \left(n_{\vec{k}} + \frac{1}{2} \right) \hbar\omega_{\vec{k}}, \qquad (3.5.7)$$

where $n_{\vec{k}}$ is the number of quanta of EM field (i.e., of photons) with the wave vector $\vec{k}$. The basic (vacuum) state of EM field is characterized by the absence of real photons at $n_{\vec{k}} = 0$. In this case the energy of EM field occurs to be an infinite value:

$$\varepsilon_0 = \frac{\hbar}{2} \sum_k \omega_{\vec{k}}, \qquad (3.5.8)$$

In the quantum field theory all observed energies are counted from the energy of vacuum ε_o. In practice this is reduced to the subtraction ε_o from all values in question. In particular, for the vacuum of EM field the observed energy is equal to 0. Average values of electrical and magnetic field in the vacuum state are equal to 0, but average values from the squares of these values are different from zero, which leads to the consequences observed during the experiment (see below). This means that EM fields in the vacuum are oscillated. These fluctuations are called the zero point oscillations of EM field.

The said testifies that vacuum should be understood as the field in one of its states, i.e., as a certain matter system. On this base (Wilczek, 1999) "*Following Einstein, Paul Dirac* (1902-1984) *then showed that photons emerged as a logical consequence of applying the rules of quantum mechanics to Maxwell's electromagnetic aether. This connection was soon generalized so that particles of any sort could be represented as the small-amplitude excitations of quantum fields. Electrons, for example, can be regarded as excitations of an electron field, an aether that pervades all space and time uniformly. Our current and extremely successful theories of the strong, electromagnetic, and weak forces are formulated as relativistic quantum field theories with local interactions."*

Thus (Levich et al., 1973), from the point of view of contemporary electrodynamics "emptiness", i.e., the absence of elementary particles and photons, is not "nothing", but is a specific state of field, named physical vacuum.

5.4. Experimental proofs of existence of quantized electromagnetic aether

The indicated representation of the field in the form of oscillators gives the theoretical predictions, which describe well some thin effects of interaction of electron with EM aether both in classical and quantum physics.

Unfortunately, as Feynman noted, "*In quantum electrodynamics the field is again represented as a set of oscillators. But the motion of the oscillators cannot be worked out and the oscillators eliminated*", which leads to the known infinities. Bethe (Bethe, 1947) managed to overcome these, proposing the procedure of renormalization with the necessity of subtracting two infinite terms.

Although the operation of renormalization leads to very accurate calculated results, as it was noted by many scientists (for example, by Feynman), the operation of renormalization is not correct.

If we use an idea of the particles as of the oscillators of EM field with limited sizes, in many incidents it is possible to calculate the same values without the renormalization. Let us give briefly some examples.

We will use the book: (Levich et al., 1973), and also the article by Th. Welton (Welton, 1948).

In particularity, the phenomenon of Lamb displacement gives an illustrative example of the correctness of those ideas, which were assumed as the basis of the quantum theory of emission and positron theory (Welton, 1948):

"*An intuitive explanation is given for the electromagnetic shift of energy levels by calculating the mean square amplitude of oscillation of an electron coupled to the zero-point fluctuations of the electromagnetic field.*

II. The mean square fluctuation in position of a free electron

Our starting point is the observation that the quantum-mechanical zero-point variation of the radiation field in empty space gives rise to fluctuating electric and magnetic fields whose mean square values at a point in space are given by the well-known relation

$$\left\langle \mathrm{E}_{0\omega}^{2} \right\rangle = \left\langle \mathrm{H}_{0\omega}^{2} \right\rangle = \frac{2\hbar c}{\pi} \int_{0}^{\infty} k^{3} dk \,, \qquad (3.5.9)$$

In this equation the variable k refers to the wave number of a quantum, and the contribution to the mean square fluctuation arising from frequencies in the range cdk is therefore explicitly displayed.

Equation (3.5.9) *can be simply derived by ascribing to every normal mode of the radiation field an energy which is just the zero-point energy for an oscillator with the frequency of the normal mode. The total energy can be written either as the volume integral of the ordinary electromagnetic energy density or as a sum over normal modes, and Eq,* (3.5.9) *merely states the equality of these two forms.*

It will now be assumed that an otherwise free electron is acted on by these fluctuating fields. The electron will be assumed to move with non-relativistic velocities so that if $\vec{r}$ *is its position vector, the equation of motion is*

$$m\frac{d^{2}\vec{r}}{dt^{2}} = e\vec{E} \,, \qquad (3.5.10)$$

The vector $\vec{E}$ *is the fluctuating field specified by* (3.5.9)*, Since Eq.* (3.5.10) *is linear, we can regard it as a classical equation for the quantum-mechanical expectation value of* $\vec{r}$ *. For a given harmonic component of* $\vec{E}$ *the solution of* (3.5.10) *is obvious. We perform this integration, find the resulting value of and sum over frequencies using* (1)*. We then obtain a quantity* $\left\langle \left(\Delta r^{2} \right) \right\rangle$*, defined as the mean square fluctuation in position of a free electron*

$$\left\langle \left(\Delta r^2\right) \right\rangle = \frac{2}{\pi}\frac{e^2}{\hbar c}\left(\frac{\hbar}{mc}\right)^2 \int_{k_0}^{\kappa} \frac{dk}{k}, \qquad (3.5.11)$$

Consider the motion of an electron in a static field of force specified by a potential energy $V(\vec{r})$. The coordinates of the electron consist of two parts: the smooth part $\vec{r}$ and the random part $\Delta\vec{r}$. The instantaneous potential energy is then given by

$$V(r+\Delta r) = \left[1 + \Delta r \cdot \vec{\nabla} + \frac{1}{2}\left(\Delta r \cdot \vec{\nabla}\right)^2 + \ldots\right] V(r), \qquad (3.5.12)$$

The effective potentizl energy in which the particle moves will just be the average of (5) over all values of Δr. Remembering that Δr has an isotropic spatial distribution, we obtain

$$\left\langle V(r+\Delta r) \right\rangle = \left[1 + \frac{1}{6}\left\langle (\Delta r)^2 \right\rangle \vec{\nabla}^2 + \ldots\right] V(r), \qquad (3.5.13)$$

(With the correct selection of the upper and lower limits of integration in (3.5.11) **)** *we thus see that the existence of the position fluctuation of the electron will effectively modify the potential in which it moves by the addition of a term proportional to the Laplacian of the potential energy…*

The magnitude of this mean square fluctuation in position will be very small for any reasonable kt, but an observable effect will arise when the electron moves in a potential with a large curvature."

Also Welton examined with success the several simple processes involving the interaction of electrons with other particles and electron radiation (Lamb shift, low energy Compton scattering, the interaction between a spin and a magnetic field):

"For example, in the case of the ***Lamb shift t****he correction to the energy of a stationary state of the atom with wave function $\psi(\vec{r})$ will be*

$$\Delta\varepsilon = \frac{4e}{3}\frac{e^2}{\hbar c}\left(\frac{\hbar}{mc}\right)^2 \ln\frac{mc^2}{\hbar c k_0}\left|\psi(0)\right|^2, \qquad (3.5.13)$$

*This expression will be recognized as identical with the expression derived by Bethe for the level shift. The quantity $\hbar c k_0$ should clearly be taken equal to the average excitation energy (*17.8Ry*) (*Ry - *Rydbergs) introduced by Bethe,* (Bethe, 1947)] *in order to obtain approximate agreement with the experimental result of Lamb….*

The derivation just given has some attractive features. It gives a convergent result for the physically meaningful part of the reaction of the field on the electron, without the necessity of subtracting two infinite terms."

6.0. Higgs's mechanism of mass generation

6.1. Introduction. Basic principles

"Einstein first purified, and then enthroned, the aether concept. As the 20th century has progressed, its role in fundamental physics has only expanded. At present, renamed and thinly disguised, it dominates the accepted laws of physics." Frank Wilczek. The Persistence of Ether. (Physics Today, 52, 11-13, January 1999) http://xserver2.lns.mit.edu/~csuggs/physics_today/wilczekpubs.html

The concept that what we ordinarily perceive as empty space is in fact a complicated medium is a profound and pervasive theme in modern physics. This invisible inescapable medium alters the behavior of the matter that we do see. Just as Earth's gravitational field allows us to select a unique direction as up, and thereby locally reduces the symmetry of the underlying equations of physics, so cosmic fields in "empty" space lower the symmetry of these fundamental equations everywhere. For although this concept of a symmetry-breaking aether has been extremely fruitful (and has been demonstrated indirectly in many ways), the

ultimate demonstration of its validity --cleaning out the medium and restoring the pristine symmetry of the equations -- has never been achieved: that is, perhaps, until now.
Frank Wilczek. High-energy physics: An emptier emptiness? *Nature,* **435**, 152-153 (12 May 2005) http://scienceweek.com/2005/sw050708-6.htm

In the classical field theory the appearance of mass is not directly connected with the interaction of elementary particles with the physical vacuum. The generation of mass occurs here as a result of interaction of the particle field with itself. If we speak about the influence of physical vacuum on the energy states of the connected particles (for example, electron with proton in the hydrogen atom), then the discussion here only deals with the correction of the energy of electron. A similar influence on free particles is not noted.

In a different way mass is introduced in the Standard Model. In the SM the physical vacuum is used for the particles mass generation description, which the Nobel laureate Frank Wilczek also calls aether, and which consists of the oscillators of scalar massive boson field - Higgs's field.

In order to explain, which is the reason why this way of introduction of mass was selected and how this is realized, let us briefly examine, what is interaction of particle with vacuum and how the mechanism of the generation of mass in SM works.

"*It is assumed* (Practicum, 2004) *in Standard Model that besides fields of particles, an additional field exists, which is practically separated from the empty space. It is conventionally named as Higgs's field. It is considered that entire space is filled with this field and that particles acquire mass by interaction with it. Those of them, which strongly interact with Higgs's field, are heavy particles, and weakly interacting particles are lihgt. This effect is analogous to the effect of the motion of a body in a viscous fluid, when due to interaction with the liquid, it acquires additional effective mass. One additional example is electron in a crystal. Because of electromagnetic interaction with the atoms of crystal lattice the electron acquires an effective mass, different from the mass of free electron."*

"*The theory* (Ivanov, 2007, 2007a) *is based on the specific symmetry between the electromagnetic and weak interactions - electro-weak symmetry. It is considered that this symmetry was in the early universe and because of it the particles were mass-free. But symmetry was spontaneously destroyed in some stage of evolutions, and particles acquired mass, since we know from the experience that in our world these particles are massive. Higgs mechanism is exactly that driving force, which disrupts this symmetry.*

This happens in the following way. In the quantum theory all particles are the quanta, which are oscillated "pieces" of field. For example, electrons are the oscillations of electron field, photons are oscillations of electromagnetic field, and so forth. Each field has a state with lowest energy, called "vacuum" of this field. For the usual particles the vacuum exists when particles are absent, i.e., when their field is everywhere equal to zero. If particles are present (i.e., field is not everywhere equal to zero), then this state of field possesses more energy, than vacuum.

But Higgs field is special: it has the non-zero vacuum. In other words, thestate with the lowest energy of Higgs field is when the entire space is filled by the Higgs field of some energy or (which is the same thing) mass. Other particles also move in this background. The oscillations of Higgs field relative to "vacuum average" are the quanta of Higgs field, i.e., Higgs bosons.

The presence of background Higgs field affects the particle motion by a strictly defined means: it hampers particle acceleration, but it does not prevent their uniform motion. Particles become more inert, in other words, mass appears in them. However, some particles, for example photons, do not interact directly with the Higgs field and remain mass-free…".

The mathematical procedure of the mass generation according to Higgs's mechanism is presented in many books and papers (see for example, (Dawson, 1999)). We will use recent survey that contains briefly all elements of this theory (Quigg, 2007).

6.2. Origin of mass in Standard Model

Mass remained an essence—part of the nature of things—for more than two centuries, until Abraham (1903) *and Lorentz* (1904) *sought to interpret the electron mass as electromagnetic self-*

energy... Our modern conception of mass has its roots in Einstein's pregnant question: 'Does the inertia of a body depend upon its energy content?' and his powerful conclusion, "The mass of a body is a measure of its energy content; if the energy changes by L, the mass changes in the same sense by [L/c^2, where c is the speed of light]". Mass is rest energy.... Among the virtues of identifying mass as $m = \varepsilon_0 / c^2$ *, where* ε_0 *designates the body's rest energy, is that mass, so understood, is a Lorentz-invariant quantity, given in any frame as*

$$m = \left(1/c^2\right)\sqrt{\varepsilon^2 - p^2c^2}\ , \qquad (3.6.1).$$

But not only is Einstein's a precise definition of mass, it invites us to consider the origins of mass by coming to terms with a body's rest energy.

6.3. Sources of mass in the electroweak theory

We build the standard model of particle physics on a set of constituents that we regard provisionally as elementary: the quarks and leptons, fundamental forces derived from gauge symmetries. The quarks are influenced by the strong interaction, and so carry colour, the strong-interaction charge, whereas the leptons do not feel the strong interaction and are colourless. We idealize the quarks and leptons as pointlike, because they show no evidence of internal structure at the current limit of our resolution ($r \le 10^{-18}$ *m). The charged-current weak interaction responsible for radioactive beta decay and other processes acts only on the left-handed fermions. Whaether the observed parity violation reflects a fundamental asymmetry in the laws of Nature, or a left-right symmetry that is hidden by circumstance and might be restored at higher energies, we do not know.*

The electroweak theory[4] (like QCD*) is a gauge theory, in which interactions follow from symmetries. Already in the* 1930*s, Fermi and Klein proposed descriptions of the weak interaction in analogy to the emerging theory of quantum electrodynamics (*QED*). The correct electroweak gauge symmetry, which melds the* $SU(2)_L$ *family (weak-isospin) symmetry suggested by the left-handed doublets of figure 1 with a* $U(1)_Y$ *weak-hypercharge phase symmetry, emerged through trial and error, guided by experiment. We characterize the* $SU(2)_L \otimes U(1)_Y$ *theory by the left-handed quarks*

$$\mathrm{L}_q^{(2)} = \begin{pmatrix} c \\ s \end{pmatrix}_L \ \mathrm{L}_q^{(3)} = \begin{pmatrix} t \\ b \end{pmatrix}_L , \qquad (3.6.2)$$

with weak isospin $I = 1/2$ *and weak hypercharge* $Y(\mathrm{L}_q) = 1/3$*; their right-handed weak-isoscalar counterparts*

$$\mathrm{R}_u^{(1,2,3)} = u_R, c_R, t_R \ \text{and}\ \mathrm{R}_d^{(1,2,3)} = d_R, s_R, b_R, (3.6.3)$$

with weak hypercharges $Y(\mathrm{R}_u) = 4/3$ *and* $Y(\mathrm{R}_d) = -2/3$*; the left-handed leptons*

$$\mathrm{L}_e = \begin{pmatrix} \nu_e \\ e^- \end{pmatrix}_L \ \mathrm{L}_\mu = \begin{pmatrix} \nu_\mu \\ \mu^- \end{pmatrix}_L \ \mathrm{L}_\tau = \begin{pmatrix} \nu_\tau \\ \tau^- \end{pmatrix}_L , \qquad (3.6.4)$$

with weak isospin $I = 1/2$ *and weak hypercharge* $Y(\mathrm{L}_l) = -1$*; and the right-handed weak-isoscalar charged leptons*

$$\mathrm{R}_{e,\mu,\tau} = e_R, \mu_R, \tau_R , \qquad (3.6.5)$$

with weak hypercharge $Y(\mathrm{R}_l) = -2$*. (Weak isospin and weak hypercharge are related to electric charge through* $Q = I_3 + (1/2)Y$*. Here we have idealized the neutrinos as massless.*

The $SU(2)_L \otimes U(1)_Y$ *electroweak gauge group implies two sets of gauge fields: a weak isovector* $\vec{b}_\mu$*, with coupling constant g, and a weak isoscalar* A_μ*, with independent coupling constant g'. The gauge fields compensate for the variations induced by gauge transformations,* *provided that they obey the transformation laws* $\vec{b}_\mu \to \vec{b}_\mu - \vec{\alpha} \times \vec{b}_\mu - (1/g)\partial_\mu \vec{\alpha}$ *under an infinitesimal weak-isospin rotation generated by* $G = 1 + (i/\vec{\alpha} \cdot \vec{\tau})$ *(where* $\vec{\tau}$ *are the Pauli isospin matrices) and* $A_\mu \to A_\mu - (1/g)\partial_\mu \vec{\alpha}$ *under an infinitesimal hypercharge phase rotation. Corresponding to these gauge fields are the field-strength tensors*

$$F^l_{\mu\nu} = \partial_\nu b^l_\mu - \partial_\mu b^l_\nu + g\varepsilon_{jkl} b^j_\mu b^k_\nu, \qquad (3.6.6)$$

for the weak-isospin symmetry, and

$$f_{\mu\nu} = \partial_\nu A_\mu - \partial_\mu A_\nu, \qquad (3.6.7)$$

for the weak-hypercharge symmetry.

We may summarize the interactions by the Lagrangian

$$L = L_{\text{gauge}} + L_{leptons} + L_{quarks}, \qquad (3.6.8)$$

with

$$L_{gauge} = -\frac{1}{4}\vec{F}_{\mu\nu}\vec{F}^{\mu\nu} - \frac{1}{4} f_{\mu\nu} f^{\mu\nu}, \qquad (3.6.9)$$

$$L_{leptons} = \overline{\mathrm{R}}_l i\gamma^\mu \left(\partial_\mu + i\frac{g'}{2} A_\mu Y\right)\mathrm{R}_l + +\overline{\mathrm{L}}_l i\gamma^\mu \left(\partial_\mu + i\frac{g'}{2} A_\mu Y + i\frac{g}{2}\vec{\tau}\cdot\vec{b}_\mu\right)\mathrm{L}_l, \qquad (3.6.10)$$

where l runs over e, μ, τ*, and*

$$\begin{aligned} L_{quarks} = {} & \overline{\mathrm{R}}^{(n)}_{\mathrm{u}} i\gamma^\mu \left(\partial_\mu + i\frac{g'}{2} A_\mu Y\right)\mathrm{R}^{(\mathrm{n})}_{\mathrm{u}} + \overline{\mathrm{R}}^{(n)}_{\mathrm{d}} i\gamma^\mu \left(\partial_\mu + i\frac{g'}{2} A_\mu Y\right)\mathrm{R}^{(\mathrm{n})}_{\mathrm{d}} + \\ & + \overline{\mathrm{L}}^{(\mathrm{n})}_{\mathrm{q}} i\gamma^\mu \left(\partial_\mu + i\frac{g'}{2} A_\mu Y + i\frac{g}{2}\vec{\tau}\cdot\vec{b}_\mu\right)\mathrm{L}^{(\mathrm{n})}_{\mathrm{q}} \end{aligned}, \qquad (3.6.11)$$

where n runs over 1, 2, 3.

Although the weak and electromagnetic interactions share a common origin in the $SU(2)_\mathrm{L} \otimes U(1)_\mathrm{Y}$ *gauge symmetry, their manifestations are very different. Electromagnetism is a force of infinite range, while the influence of the charged-current weak interaction responsible for radioactive beta decay only spans distances shorter than about* 10^{-15} *cm. The phenomenology is thus at odds with the theory we have developed to this point. The gauge Lagrangian* (3.6.9) *contains four massless electroweak gauge bosons, namely* $A_\mu, b^1_\mu, b^2_\mu, b^3_\mu$*, because a mass term such as* $\frac{1}{2}m^2 A_\mu A_\mu$ *is not invariant under a gauge transformation. Nature has but one: the photon. Moreover, the* $SU(2)_\mathrm{L} \otimes U(1)_\mathrm{Y}$ *gauge symmetry forbids fermion mass terms* $m\bar{f}f = m(\bar{f}_R f_L + \bar{f}_L f_R)$ *in* (3.6.10) *and* (3.6.11)*, because the left-handed and right-handed fields transform differently.*

To give masses to the gauge bosons and constituent fermions, we must hide the electroweak symmetry, recognizing that a symmetry of the laws of Nature does not imply that the same symmetry will be manifest in the outcomes of those laws. How the electroweak gauge symmetry is spontaneously broken—hidden—to the $U(1)_{\mathrm{em}}$ *phase symmetry of electromagnetism is one of the most urgent and challenging questions before particle physics.*

The superconducting phase transition offers an instructive model for hiding the electroweak gauge symmetry. To give masses to the intermediate bosons of the weak interaction, we appeal to the Meissner effect—the exclusion of magnetic fields from a superconductor, which corresponds to the photon developing a nonzero mass within the superconducting medium. What has come to be called the Higgs mechanism is a relativistic generalization of the Ginzburg-Landau phenomenology of superconductivity[6]*. The essential insight is that the Goldstone theorem does not operate when a local gauge symmetry, as opposed to a continuous global symmetry, is broken. Instead, a miraculous interplay between the would-be Goldstone bosons and the normally* *massless gauge bosons endows gauge bosons with mass and removes the massless scalars from the spectrum.*

Let us see how spontaneous symmetry breaking operates in the electroweak theory. We introduce a complex doublet of scalar fields

$$\phi \equiv \begin{pmatrix} \phi^{+} \\ \phi^{0} \end{pmatrix}, \tag{3.6.12}$$

with weak hypercharge $Y_{\phi} = +1$. *Next, we add to the Lagrangian new (gauge-invariant) terms for the interaction and propagation of the scalars,*

$$L_{scalar} = \left(D^{\mu}\phi\right)^{+}\left(D_{\mu}\phi\right) - V\left(\phi^{+}\phi\right), \tag{3.6.13}$$

where the gauge-covariant derivative is

$$D_{\mu} = \partial_{\mu} + i\frac{g'}{2}A_{\mu}Y + i\frac{g}{2}\vec{\tau}\cdot\vec{b}_{\mu}, \tag{3.6.14}$$

and (inspired by Ginzburg and Landau) the potential interaction has the form

$$V\left(\phi^{+}\phi\right) = \mu^{2}\left(\phi^{+}\phi\right) + |\lambda|\left(\phi^{+}\phi\right)^{2}, \tag{3.6.15}$$

We are also free to add gauge-invariant Yukawa interactions between the scalar fields and the leptons (l runs over e, μ, τ *as before),*

$$L_{Yukawa-l} = -\zeta_{l}\left[\left(\overline{\mathrm{L}}_{l}\phi\right)\mathrm{R}_{l} + \overline{\mathrm{R}}_{l}\left(\phi^{+}\mathrm{L}_{l}\right)\right], \tag{3.6.16}$$

and similar interactions with the quarks.

We then arrange their self-interactions so that the vacuum state corresponds to a broken-symmetry solution. The electroweak symmetry is spontaneously broken if the parameter μ^{2} *is taken to be negative. In that event, gauge invariance gives us the freedom to choose the state of minimum energy—the vacuum state—to correspond to the vacuum expectation value*

$$\langle\phi\rangle = \begin{pmatrix} 0 \\ \upsilon/\sqrt{2} \end{pmatrix}, \tag{3.6.17}$$

where $\upsilon = \sqrt{-\mu^{2}/|\lambda|}$.

Let us verify that the vacuum of (3.6.17) *does break the gauge symmetry* $SU(2)_{\mathrm{L}} \otimes U(1)_{\mathrm{Y}}$ —> $U(1)_{\mathrm{em}}$. *The vacuum state* $\langle\phi\rangle$ *is invariant under a symmetry operation corresponding to the generator* G *provided that* $e^{i\alpha\mathrm{G}}\langle\phi\rangle = \langle\phi\rangle$, *i.e. if* $\mathrm{G}\langle\phi\rangle = 0$. *Direct calculation reveals that the original four generators are all broken, but electric charge is not. The photon remains massless, but the other three gauge bosons acquire masses, as auxiliary scalars assume the role of the third (longitudinal) degrees of freedom.*

Introducing the weak mixing angle θ_{W} *and defining* $g' = g\tan\theta_{W}$, *we can express the photon as the linear combination* $A = A\cos\theta_{W} + b_{3}\sin\theta_{W}$. *We identify the strength of its (pure vector) coupling to charged particles,* $gg'/\sqrt{g^{2} + g'^{2}}$ *with the electric charge e. The mediator of the charged-current weak interaction,* $W^{\pm} = \left(b_{1} \mp ib_{2}\right)/\sqrt{2}$ *acquires a mass* $M_{W} = g\upsilon/2 = e\upsilon/2\sin\theta_{W}$.

The electroweak gauge theory reproduces the low-energy phenomenology of the V-A theory of weak interactions, provided we set $\upsilon = \left(\mathrm{G}_{\mathrm{F}}\sqrt{2}\right)^{-1/2}$ 246GeV, *where* G_F = 1.16637(1) x 10^{-5} GeV^{-2} *is Fermi's weak-interaction coupling constant. It follows at once that* $M_w \approx 37.3\mathrm{GeV}/\sin\theta_{W}$. *The combination of the* I_{3} *and Y gauge bosons orthogonal to the photon is the mediator of the* *neutral-current weak interaction,* $Z = b_3 \cos\theta_W - A\sin\theta_W$, *which acquires a mass* $M_Z = M_W / \cos\theta_W$. *The weak neutral-current interaction was not known before the electroweak theory. Its discovery in* 1973 *marked an important milestone, as did the observation a decade later of the* $W^{\pm}$ *and* Z^0 *bosons.*

Three decades of extensive studies of the weak neutral current culminated in experiments at the $e^+e^- \to Z$ *factories. The* ALEPH, DELPHI, L3, *and* OPAL *detectors accumulated* 17 *million Z decays at* LEP, *and the SLD detector recorded* 600 *thousand Z decays using polarized beams at the Stanford Linear Collider. A broad collection of experimental measurements and the supporting theoretical calculations have elevated the electroweak theory to a law of Nature, tested as a quantum field theory at the level of one part in a thousand. The mass of the neutral weak boson is known to impressive precision,* M_Z = 91.1876±0.0021 GeV, *while the world average W-boson mass is Mw* = 80.398 ± 0.025 GeV. *One noteworthy achievement is a clear test of the electroweak gauge symmetry in the reaction* $e^+e^- \to W^+W^-$*". in fine agreement with theory."*

It is not difficult to see that the Lagrangian of the EM wave theory of matter (3.4.10)

$$L = \frac{1}{2}\left\{\left(\frac{\partial\vec{\Phi}}{\partial t}\right)^2 - c^2\left(\vec{\nabla}\vec{\Phi}\right)^2 - c^2 m^2 \vec{\Phi}^2\right\} \equiv -\frac{1}{2}c^2\left\{\sum_\nu\left(\frac{\partial\vec{\Phi}}{\partial x_\nu}\right)^2 + m^2\vec{\Phi}\vec{\Phi}^+\right\} \equiv \partial_\nu\vec{\Phi}\partial^\nu\vec{\Phi} - c^2 m^2\vec{\Phi}^2$$

is similar to Lagrangian of the Higgs field (3.6.13)

$$L_{scalar} = \left(D^\mu\phi\right)^+\left(D_\mu\phi\right) - V\left(\phi^+\phi\right),$$

if the usual derivative ∂_ν of Lagrangian (3.4.10) was replaced by the gauge-covariant derivative D_ν in accordance with (3.6.14). In contrast with the spontaneous transformation of mass-free field into massive, which is described by Higgs's mechanism, in the wave EM theory of matter, only the wave field itself participates in the transformation, but not its vacuum. We will examine more consecutively how this occurs in the following chapters of nonlinear theory.

Bibliography

Akhiezer, A.I. and Berestetskii,. W.B. (1965). *Quantum electrodynamics*. Moscow, Interscience publ., New York.

Bateman, H. (1915). The mathematical analysis of electrical and optical wave-motion on the basis of maxwell's equations. Cambridge, Printed by John Clay, M.A. at the university press 1915

Becker, Richard. (1982). Electromagnetic fields and interactions, Vol. 1-2. Editor Fritz Sauter. Dover edition, 1982.

Bethe, H.A. (1947) Phys. Rev. 72, 339 (1947)

Bohr, N. and Rosenfeld, L. (1933). Zur Frage der Mesbarkeit der electromagnetische Feldgroessen. Mat.-fys. Medd. Dan. Vid. Selsk., 12, № 8; (Trans. into English, 1979)

Broglie, de, L.(1941). Problems de Popagations Guidees des Ondes. Electromagnetiques. Paris, 1941.

Bulgakov, N. (1911). On nature of electron. (in Russian). Zh. R.F. - X. O. Fizich. Otd. Tom XLIII, iss. 8, 1911.

Crawford Jr., F.S. (1968) Waves: Berkeley Physics Course, Vol. 3 . McGraw-Hill Book Co.,1968

Dawson, S. (1999). Introduction to Electroweak Symmetry Breaking. http://arxiv.org/abs/hep-ph/9901280

Dirac, P.A.M. (1927). The Quantum Theory of the Emission and Adsorbtion of radiation. Proc. Roy. Soc., A114, 243.

Ehrenfest, Paul. (1913). Zur Krise der Lichtäther-Hypothes. Berlin, 1913

Einstein, A. (1920). Aether and the Theory of Relativity. http://press.princeton.edu/catalogs/series/cpe.html

Fadner, W.L. (1988). American Journal of Phydsics, **56**, pp. 114-122.

Fermi, E. (1922). Physik. Z., 23, 340 (1922), or Atti accad. nazl. Lincei Rend., 31, 184, 306 (1922).

Fermi, E. (1932) Quantum theory of radiation. Reviews of modern physics, vol. 4, January, 1932.

Feynman, R. (1948). Space-time approach to non-relativistic quantum mechanics. Rev. Mod. Phys., 20, № 2, 367.

Feynman, R.P., Leighton, R.B., Sands, M., (1964). The Feynman Lectures on Physics.. V. 6. Ch. 28

Goldstein, L.D. and Zernov, N.V. (1971). Electromagnetic fields and wave. (in Russian). Moscow, Publication "Soviet radio". 1971.

Gottfried, K. and Weisskopf, V.F. (1984). Concepts of Particle Physics. Vol. 1. Oxford Univercity Press – New York, 1984..

Hasenoehrl, F. (1904). Zur Theorie der Strahlung in bewegten Koerpern. Ann. der Phys. (ser 4), **15**, 344-370, (1904)

Hasenoehrl, F. (1905). Zur Theorie der Strahlung in bewegten Koerpern. Ann. der Phys. (ser 4), **16**, 589-592, (1905)

Ivanov, I.P. (2007). Higgs mechanism of the breakdown of electro-weak symmetry (in Russian) (http://elementy.ru/LHC/HEP/higgs_theory)

Ivanov, I.P. (2007a). Higgs mechanism in the analogies (in Russian) (http://elementy.ru/LHC/HEP/higgs_theory/explanations)

Jackson, J.D. (1999). Classical Electrodynamics, 3rd ed., 808 pp. Wiley, New York.

Jimenez, J. L. and Campos, I. (1999). Models of the classical electron after a century. Foundations of Physics Letters, Vol. 12, No. 2, 1999

Kudryavtsev, P. S. (1971). History of physics. (in Russian) (Part III. Chapter 1. Electrodynamics of the moving media and electronic theory). Moscow: Publication "Education", 1971.

Kwal, B. (1949). J. phys. radium, 10, 103 (1949).

Kyriakos, A.G. (2004a) An Electromagnetic Form of the Dirac Electron Theory http://redshift.vif.com/JournalFiles/V11NO2PDF/V11N2KYR.pdf

Kyriakos, A.G. (2004b) The Dirac Electron Theory as an Approximation of Nonlinear Electrodynamics http://redshift.vif.com/JournalFiles/V11NO3PDF/V11N3KYR.pdf

Kyriakos, A.G. (2005) The massive neutrino-like particle of the non-linear electromagnetic field theory http://redshift.vif.com/JournalFiles/V12NO1PDF/V12N1KYR.pdf

Kyriakos, A.G. (2009) The Nonlinear Quantum Field Theory as a Generalization of Standard Model http://www.amazon.com/Nonlinear-Generalization-Standard-Geometrical-Approach/dp/0980966744

Kyriakos A.G. (2010a). Comparison of the algorithmic and axiomatic approaches to the construction of quantum field theory http://vixra.org/abs/1003.0169

Kyriakos A.G. (2010b) Theory of Elementary Particles 1. Choice of Axiomatics and Mathematical Apparatus of Theory. http://vixra.org/abs/1005.0019

Kyriakos, A.G. (2010c). Nonlinear Theory of Elementary Particles 2. The Photon Theory. http://vixra.org/abs/1006.0029

Landau, L. D. and Lifshitz, E.M. (1975). The Classical Theory of Fields, Fourth Edition: Volume 2 (Course of Theoretical Physics Series). Reed Educational and Proffessional Publishing.

Levich, V. G., Myamlin, V A., Vdovin, Yu.A., (1973). Theoretical physics. Vol. 2. North-Holland Publishing Co, (Amsterdam, London).

Lodge, Oliver. (1909) The ether of space. New York and London, Harper brothers, 1909

Lorentz. H.A. (1916). The theory of electrons. 2nd edition, Leipzig. B.G. Teubner, 1916

Martynenko, A. P. (2001). Vacuum in the contemporary quantum theory. (in Russian) SOJ, Vol. 7, №5, 2001.

Nambu, Y. (1949). Prospects of elementary particle physics. The collection of translation from Japan to Russian. Edited by A.S. Davydov. – Kiev, Publication: Naukova Dumka, 1982.

Pamyatnykh, E.A. (2001). Electrodynamics: Special theory of relativity. Theory of electromagnetic field. (in Russian) Publishing house of Ural University, 2001.

Polyakov, A.M. (1987). Gauge Fields and Strings. Harwood Academic Publishers, 1987.

Practicum, (2004). Practice. Particles and atomic nuclei. (in Russian). , Moscow, Moscow State Univercity, 2004. http://nuclphys.sinp.msu.ru/p/zad_09.pdf

Pursell, E.M. (1984)Electricity and Magnetism (Berkeley Physics Course, Vol. 2), 1984.

Quigg, Chris. (2007) Spontaneous symmetry breaking as a basis of particle mass. Rep. Prog. Phys. 70 (2007) 1019-1053. (http://iopscience.iop.org/0034-4885/70/7/R01)

Richardson, O.W. (1916). The electron theory of matter/ Cambridge University Press, 1916.

Rohrlich, F. (1960). Am. J. Phys., 28, 639 (1960).

Schrödinger, E. (1952). Are There Quantum Jumps? The British Journal for the Philosophy of Science, Part I. Vol. 3, No. 10 (Aug., 1952), pp. 109-123); Part II. Vol. 3, No. 11 (Nov., 1952), pp. 233-242).

Schwinger, J., (1948). On Quantum-Electrodynamics and the Magnetic Moment of the Electron. Phys. Rev. 73, 416–417 (1948)

Shirkov, D.V. and Belokurov, V.V. (1991). The Theory of Particle Interactions (Translation Series) Springer Verlag, 1991

Spasskiy, B.I. (1977). History of physics. (in Russian). Vol. 2., Moscow, Publication "High Education Scoole", 1977 .

The authors. (2005) Edited by Marco Mamone Capria. Physics before and after Einstein. IOS press, 2005

The Great Soviet Encyclopedia, 3rd Edition (1970-1979). Maxwell-Lorentz equations © 2010 The Gale Group, Inc.

Thomson, J.J. (1881) On the Electric and Magnetic Effects produced by the Motion of Electrified Bodies. Phil. Mag. 1981 , v.11, pp. 229-249.

Thomson, J.J. (1907). The corpuscular theory of matter. New York, Charles Scribner's sons, 1907

Welton, Th. (1948). Some observable effects of the quantum-mechanical fluctuations of the electromagnetic field. Phys. Rev., 74, 1157 (1948)

Wentzel, Gregor (2003). Quantum Theory of Fields. Dover edition, 2003.

Whittaker, E. T. (1910). A history of the theories of aether and electricity : from the age of Descartes to the close of the nineteenth century (1910) http://www.archive.org/details/historyoftheorie00whitrich

Wilczek, Frank. (1999). The Persistence of Ether. (Physics Today, 52, 11-13, January 1999) http://xserver2.lns.mit.edu/~csuggs/physics_today/wilczekpubs.html

Wilczek, Frank. (2005) High-energy physics: An emptier emptiness? Nature, 435, 152-153 (12 May 2005) http://scienceweek.com/2005/sw050708-6.htm

Wilson, W. (1936). Proc. Phys. Soc. (London), A48, 376 (1936).