



## ONCE AGAIN ABOUT THE PROBLEM "4/3"

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### Abstract:

*It is shown that the problem "4/3" or the problem of electromagnetic mass has a strict solution only if the fields are instantaneous. This result is valid in both the classical and relativistic variants. The hypothesis of the existence of a physical ether is introduced, which allows us to explain the constancy of the speed of light in inertial reference systems and features of instantaneous action at a distance.*

**Keywords:** 4/3 Problem; Electromagnetic Mass.

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### 1. Introduction

In 1881, the eminent British physicist J. J. Thomson [1] published an article "On the electrical and magnetic effects produced by the movement of electrified bodies", in which he introduced the concept of "electromagnetic mass". He, considering the relationship between the electric and magnetic field of the charge, suggested that at least some of the mechanical mass is of electromagnetic origin. It is interesting that he made this assumption even before the discovery of an electron made by him in 1897.

Naturally, he tried to explain the mass of the particle discovered by him precisely as "electromagnetic", i.e. using Maxwell's electromagnetic field theory. Later in the book "Electricity and Matter", published in 1903 [2], he expressed the hypothesis that the entire mass of an electron has an electromagnetic nature. It is clear that, in the event that his hypothesis was confirmed, a direct path opened up to the unification of the electromagnetic and gravitational fields.

This idea was ahead of the development of physics by a century. However, for its implementation, scientists had to go a long way, overcoming errors and delusions. Due to the effect of self-induction, electrostatic energy behaves like an object having an electromagnetic mass and some momentum.

A charged particle creates an electromagnetic field, according to Maxwell's theory. This field has energy. There is a tempting idea to the famous formula  $E = mc^2$  to describe the rest mass of a

charge<sup>1</sup>. This idea was developed by Oliver Heaviside (1889) [5], Thomson (1893), George Frederick Charles Searle (1897), Max Abraham (1902), Hendrik Lorenz (1892), etc.

The great scientists could not solve the main problems. Usually list the following:

- 1) The so-called “4/3 problem”, which consists in the fact that when calculating the electromagnetic field pulse of a moving electron, it turned out to be inconsistent with its electromagnetic mass calculated for a stationary electron.
- 2) The “problem” of the impossibility of ensuring the stability of an electron (like any other charged particle), only due to electromagnetic interaction, formulated by Henri Poincare.
- 3) The need to explain the mass of neutral particles.
- 4) We see the reason in the incorrect formulation of the problem and in the prejudices that prevented the solution of the problem. In the article, we will consider the cause of the “4/3” problem, a mathematically rigorous solution to this problem (without hypotheses), as well as numerous consequences of solving the electromagnetic mass problem for physics.

## 2. How Did The 4/3 Problem Arise?

According to J. Thomson, the electromagnetic mass of the charge field is

$$m_e = \frac{1}{c^2} \int w dV = \int \frac{\epsilon E^2}{2c^2} dV, \quad (2.1)$$

Where:  $w$  is the energy density of the electric field of the charge.

In 1884, Poynting derived his conservation law for Maxwell's equations:

$$\text{div } \mathbf{S} + \frac{\partial w}{\partial t} = 0, \quad (2.2)$$

Where  $\mathbf{S} = [\mathbf{E} \times \mathbf{H}]$  is the electromagnetic wave flux density. It was obvious that the electromagnetic impulse  $\mathbf{P}$  must be related to the flux density by the classical relation.

$$\mathbf{P} = m_e \mathbf{v} = \frac{1}{c^2} \int \mathbf{S} dV. \quad (2.3)$$

However, the following circumstances were clarified:

- 1) Electromagnetic mass is determined by formula (2.1), which does not depend on the shape and structure of the charge. The electromagnetic impulse  $\mathbf{P}$  depends on the structure (spatial charge distribution and shape) of the charge  $= km_e \mathbf{v}$ .
- 2) The kinetic energy of the mass  $K = m_e \frac{v^2}{2}$  also depends on these quantities.

<sup>1</sup> The formula first appeared 33 years before A. Einstein in [3]. See also [4] et al.

It turned out that the coefficient  $k$  takes the *minimum* value  $k = 4/3$ , if the charge density is distributed uniformly in a thin layer on the surface of a sphere of radius  $a$ . Any other density distributions will give ratios greater than  $4/3$ . Therefore, the problem is called “Problem  $4/3$ ”.

Consider some attempts to solve this problem.

Henri Poincaré pointed to the “problem” of electron instability, as a charged sphere. Indeed, like charges repel each other, therefore, the electron must be exposed to electrostatic forces that would have to break it. In reality, nothing of the kind happens; an electron is a stable particle, not subject to spontaneous decay. In order to solve this “problem” and at the same time solve the  $4/3$  problem, Poincaré suggested that the electron had special forces of non-electromagnetic origin, which were called “stresses (tensions, elastics) Poincaré”.

In addition, he suggested that the electron mass is composed of energy of electromagnetic and non-electromagnetic origin, and its non-electromagnetic component is negative! *It seems that this idea of Poincaré agrees with the error that formed the basis of the  $4/3$  problem: since the energy of the electromagnetic field is different from the particle mass, then there must be energy of non-electromagnetic origin, which, at the same time, will compensate for the repulsive forces of parts of the electron!*

But this idea was fundamentally not feasible. Indeed, the idea is to supplement the “bad” positive electromagnetic mass with negative “anti-bad” mass of non-electromagnetic origin so as to guarantee the stability of the electron and at the same time obtain the “correct” inertial mass. Moreover, here again difficulties arise. Why should we assume that the electron is a perfect ball, and not, for example, an ellipsoid? If the electron has the shape of an ellipsoid or simply an asymmetrical shape, then the “inertial mass” by definition, acquires “tensor” properties:  $P_i = m_{ik}v_k$ . A similar situation arises if we consider a system of interacting charges. The  $4/3$  problem has long been left without a solution, even within the framework of the classical approximation.

### 3. Solving the Problem of Electromagnetic Mass in the Classical Approximation

The solution to the electromagnetic rest mass problem was found and later published only in 1996 [6], i.e. in 100 years. Consider the approach to solving the problem. Authors write integral

$$I = \frac{1}{2} \int \rho \frac{\partial \varphi}{\partial t} dV = -\frac{\varepsilon}{2} \int \Delta \varphi \frac{\partial \varphi}{\partial t} dV. \quad (3.1)$$

Using the Gauss formula, expression (3.1) can be brought to the form:

$$I = -\frac{\varepsilon}{2} \oint \frac{\partial \varphi}{\partial t} \text{grad } \varphi \mathbf{n}^0 d\sigma + \frac{\varepsilon}{4} \int \frac{\partial (\text{grad } \varphi)^2}{\partial t} dV, \quad (3.2)$$

Where  $d\sigma$  is the volume surface,  $\mathbf{n}^0$  is the unit normal to the surface.

On the other hand, using the continuity equation for the scalar potential and charge density, expression (3.1) can be written in another form [6]:

$$I = -\frac{\varepsilon}{4} \int \frac{\partial(\text{grad } \varphi)^2}{\partial t} dV - \frac{\varepsilon}{2} \oint [\text{grad } \varphi \times [\mathbf{v} \times \text{grad } \varphi]] \mathbf{n}^0 d\sigma. \quad (3.3)$$

Comparing expressions (3.2) and (3.3), we obtain Umov's conservation law in integral form:

$$\oint (\mathbf{S}_u \cdot \mathbf{n}^0) d\sigma + \frac{\varepsilon}{2} \int \frac{\partial(\text{grad } \varphi)^2}{\partial t} dV = \oint (\mathbf{S}_u \cdot \mathbf{n}^0) d\sigma + \int \frac{\partial}{\partial t} w_e dV = 0, \quad (3.4)$$

Where

$$\begin{aligned} \mathbf{S}_u &= \frac{\varepsilon}{2} \left\{ -\frac{\partial \varphi}{\partial t} \text{grad } \varphi + [\text{grad } \varphi \times [\mathbf{v} \times \text{grad } \varphi]] \right\} = w_e \mathbf{v}, \quad w_e \\ &= \frac{\varepsilon}{2} (\text{grad } \varphi)^2. \end{aligned} \quad (3.4a)$$

In differential form, the Umov's law follows from the expression (3.4) (see [7]):

$$\text{div } \mathbf{S}_u + \frac{\partial w}{\partial t} = 0, \quad \text{i. e. } \mathbf{S}_u = w\mathbf{v}. \quad (3.4b)$$

It follows from (3.4) and (3.4a) that

$$m_e = \int \frac{1}{c^2} w_e dV, \quad \mathbf{P}_e = \frac{1}{c^2} \int \mathbf{S}_u dV = m_e \mathbf{v}. \quad (3.5)$$

Expressions (3.5) are standard relations valid for classical mechanics. Pay attention to the fact that we used mathematics *without hypotheses and did not use Poincaré's theorem*.

It remains to show that the kinetic energy  $K_e$  for the electromagnetic mass is also equal to  $K_e = m_e v^2 / 2$ .

**Law of Lenz.** Without proof, we give the Lenz law for the charge field [6]. Recall that  $\mathbf{A} = \varphi \mathbf{v} / c^2$ . So,

$$\text{div } \mathbf{S}_k + \frac{\partial w_k}{\partial t} + p_k = 0, \quad (3.6)$$

Where

$$w_k = \frac{1}{4\mu} [(\text{div } \mathbf{A})^2 + (\text{rot } \mathbf{A})^2] = \frac{w_e v^2}{2c^2} \quad (3.7)$$

is the kinetic energy density,

$$\mathbf{S}_k = -\frac{1}{2\mu} \left\{ \frac{\partial \mathbf{A}}{\partial t} \operatorname{div} \mathbf{A} + \left[ \frac{\partial \mathbf{A}}{\partial t} \times \operatorname{rot} \mathbf{A} \right] \right\} \quad (3.8)$$

is the density of the flux of Lenz,

$$p_k = -\frac{(\mathbf{j} \cdot \mathbf{A})}{4} \quad (3.9)$$

is the density of the current work in the field of the potential  $\mathbf{A}$ .

The interpretation of the Lenz law for a neutral elementary conductor with current is very interesting. In this example, there is no scalar potential (compensated by opposite charges), however, the current exists and it creates only the vector potential around itself:

$$d\mathbf{A} = \mu \frac{I(t)d\mathbf{l}}{4\pi r} . \quad (3.10)$$

We will be interested in the flow of kinetic energy  $\mathbf{S}_k$ . In the Umov law, the flow  $\mathbf{S}_u$  was associated with convective energy or mass transfer as the charge moves. The Lenz flow (kinetic energy flow) has a significant difference from the Umov flow and the Poynting flow. Let us show this by the example of an elementary current [6]. The kinetic energy flux density is:

$$d^2\mathbf{S}_k = \mathbf{r} \frac{\partial}{\partial t} d^2w_k , \quad (3.11)$$

Where

$$d^2w_k = \frac{\mu}{2} \left( \frac{I(t)d\mathbf{l}}{4\pi r} \right)^2 . \quad (3.12)$$

If the current  $I(t)$  increases, it creates a stream of kinetic energy directed from the current in the radial direction ( $d^2\mathbf{S}_k > 0$ ). The kinetic energy of the vector potential  $\mathbf{A}$  around the current increases. If the current  $I(t)$  decreases, then the Lenz flux density changes sign ( $d^2\mathbf{S}_k < 0$ ) and the energy flow rushes back to the elementary current, trying to maintain it. It is interesting to note that the Lenz flow decreases as  $1/r^3$ . Unlike the Lenz stream, the Poynting stream itself never returns to the source after radiation.

Within the *framework of classical concepts*, the electromagnetic mass problem has a strict solution. Electromagnetic mass has all the signs of an ordinary inertial mass.

#### 4. The Reasons that Prevented to Find a Solution

Surprisingly, for the same Maxwell equations, three different energy conservation laws have already been proved. These laws reflect the different sides of energy transfer. Let us keep Poynting's conservation law for future discussions. The main thing for us is to establish the fact

of the electromagnetic nature of matter, at least for small speeds of movement of charges. Why scientists for a long time could not find a solution to the problem of electromagnetic mass?

Let us turn to the works of Feynman. Feynman is not the discoverer of the “4/3 problem”. Simply in his textbook, he honestly reproduced for students the result obtained by J. J. Thomson. The reproduced result confused Feynman himself. Here is what he writes about this: *“The difference between the two formulas of electromagnetic mass is especially offensive, because quite recently we have proved that electrodynamics is consistent with the principle of relativity. In addition, the theory of relativity implicitly and inevitably assumes that the impulse must be equal to the product of energy by  $v/c^2$ . An unpleasant story! Apparently, we made a mistake somewhere. Of course, not an algebraic error in the calculations, but somewhere **overlooked something significant**”*... ([8], §4).

Why Poynting’s theorem does not give the correct result? R. Feynman encourages us to think about it. To understand the causes, we must consider the history of the development of science. Starting around the middle of the 19th century, science and technology were rapidly developing. The work of Faraday, Maxwell and other scientists allowed to make a giant step forward in the field of experiment. Discoveries “showered”, as if from a cornucopia:

**1855.** English physicist James Maxwell gave the first mathematically reasonable formulation of the theory of electromagnetism without taking into account the displacement currents.

**1861-1862.** Maxwell published several articles “On physical lines of force” (where he first introduced a displacement current).

**1873.** Maxwell’s two-volume major work, “A Treatise on Electricity and Magnetism”, was published.

**1874.** Umov. The law of conservation of energy for moving media.

**1880.** Heaviside reduced a system of 20 equations with 12 variables to 4 differential equations, known as Maxwell’s equations.

**1881.** Michelson’s experiment on the detection of ether. J. J. Thomson introduced the concept of “electromagnetic mass” into physics.

**1884.** Poynting derived his energy conservation law for electromagnetic waves.

**1888.** Hertz. Experimental evidence of the existence of electromagnetic waves.

**1892.** Lorenz derived the expression for the force acting on the charge from the fields **E** and **H**.

**1895.** Classical electrodynamics in its final form (Lorenz).

**1897.** Thomson discovers the electron.

**1899.** Lebedev experimentally discovered the pressure of the light flux and other discoveries.

In physics, two concepts confronted: the concept of long-range action and the concept of short-range action. Newton’s classic mechanics and the theory of relying on instantaneous action at a distance. Maxwell’s equations, Hertz’s experiments supported the concept of short-range action. It was an uncompromising struggle.

The lack of experience in young scientists and youthful maximalism prompted young scientists to conclude that classical physics is “outdated” and must be replaced by new physics, which could provide an explanation of the phenomena discovered in physics. The main reason for the “backwardness” of classical theories was named. This reason is an instantaneous action at a

distance that must be removed from physics. This was an erroneous conclusion, which was one of the causes of the crisis of physics.

The refusal of classical theories was also promoted by the STR of Einstein, which “forbade” any movements with velocities higher than the speed of light. Unfortunately, Einstein made a serious mistake in interpreting the Lorentz transformation [9]. At that time, confidence arose that the 4/3 problem would necessarily be solved by quantum theories. This hope turned out to be an illusion. Quantum theories themselves are faced with problems that have *classical roots*.

Analysis of Maxwell’s equations showed that electrodynamics has two branches [10]. The first branch is quasi-static electrodynamics with instant action. It describes the charge fields. The law of Umov and the law of Lenz write off the energy relations for these fields. The second branch describes the electromagnetic waves of the retarded potential. Poynting’s theorem is valid only for wave fields. The fields of electromagnetic waves and the fields of charges that have different properties. The identification of the charge fields and the fields of electromagnetic waves is the main reason for the difficulties that did not allow to solve the problem of electromagnetic mass. We note that the “magnetic paradoxes” in quasi-static electrodynamics are also due to the improper application of the Poynting vector to the charge fields.

So, at the beginning of the twentieth century, physicists made serious mistakes in the electrodynamics theory. Now, after 100 years, we must analyze electrodynamics and correct these errors.

## 5. UMOV’S Relativistic Law

Now we will show a relativistic solution to the electromagnetic mass problem. We write the Maxwell equations using 4-potentials:

$$\frac{\partial^2 A_i}{\partial x_k^2} = -\mu j_i, \quad (5.1)$$

$$\frac{\partial A_i}{\partial x_i} = 0, \quad (5.2)$$

$$\frac{\partial j_i}{\partial x_i} = 0, \quad (5.3)$$

Where

$$j_i = cq u_i, \quad A_i = \frac{\varphi u_i}{c}, \quad u_i = \frac{dx_i}{ds}. \quad (5.3a)$$

Maxwell’s equations are described by the expression (5.1); the Lorentz gauge condition is the expression (5.2); the continuity equation for a 4-current vector is (5.3). This is the standard relativistic writing of Maxwell’s equations, which is used in many textbooks. The charge rate is

constant. We will be interested in two expressions: condition (5.2) and 4-vector  $A_i$ . Classical analogues of these expressions have the form:

$$\operatorname{div} \mathbf{A}_0 + \frac{1}{c^2} \frac{\partial \varphi_0}{\partial t} = 0, \quad (5.4)$$

$$\mathbf{A}_0 = \frac{\varphi_0 \mathbf{V}}{c^2}. \quad (5.5)$$

To avoid confusion, we will assign the index “0” to the instantaneous potentials. Expression (5.5) fixes the “hard link” between the scalar and vector potentials. Recall that the instantaneous scalar potential is able to make only translational (rectilinear or curvilinear) motion in space.

Let us multiply the expression (5.1) by  $-\frac{c}{2\mu} \frac{\partial k}{\partial x_i}$  and convert the result.

**Right side:**

$$\frac{c}{2} \frac{\partial A_k}{\partial x_i} j_i = \frac{1}{2} c^2 \rho u_i \frac{\partial A_k}{\partial x_i} = \frac{1}{2} c^2 \rho u_i \frac{\partial \varphi u_k}{\partial x_i} = \frac{1}{2} c^2 \rho \varphi \frac{\partial u_k}{\partial s} = 0. \quad (5.6)$$

The right-hand side vanishes because the potential  $\varphi$  is taken in its own frame of reference, where it is independent of time, external forces do not act on the charge, and it does not experience acceleration  $\frac{\partial u_k}{\partial s} = 0$ .

**Left side;**

$$\frac{c}{2} \frac{\partial A_k}{\partial x_i} \frac{\partial^2 A_i}{\partial x_k^2} = \frac{c}{2} \frac{\partial}{\partial x_i} \left( A_k \frac{\partial^2 A_i}{\partial x_k^2} \right) = \frac{c}{2} \frac{\partial}{\partial x_i} (\mu A_{kj} j_i) = c \frac{\partial}{\partial x_i} \left( \frac{\rho \varphi}{2} u_i u_k \right) = 0. \quad (5.7)$$

Here, in the left-hand side, we obtained the expression for the divergence of the **energy flux density tensor** for the charge field. If the components of this tensor are divided by the square of the speed of light and integrated over the spatial volume, we obtain the expression for the **energy-momentum** tensor  $T_{ik}$  for a relativistic particle with electromagnetic mass  $m_e$ .

4-divergence of the tensor  $T_{ik}$  is determined by the expression

$$\frac{\partial}{\partial x_i} (T_{ik}) = \frac{\partial}{\partial x_i} (m_e c u_i u_k) = 0. \quad (5.8)$$

From the expression (5.8) it follows that the *relativistic impulse of the electromagnetic mass*  $\mathbf{P}_e$  is *constant*  $\left( \frac{\partial \mathbf{P}_e}{\partial t} = 0 \right)$ . This is obvious, since the forces on the charge do not act, and the charge moves at a constant speed. The relativistic Umov’s<sup>2</sup> energy conservation law, which has a standard form, also follows from (5.8).

<sup>2</sup> The law in non-relativistic form was established by prof. Umov in 1874 for continuous media [7].

$$\operatorname{div} \mathbf{S}_u + \frac{\partial w_0}{\partial t} = 0, \quad (5.9)$$

where  $\mathbf{S}_u = \frac{w\mathbf{v}}{\sqrt{1-(v/c)^2}}$ ,  $w_0 = \frac{q\varphi_0}{2\sqrt{1-(v/c)^2}}$  are Umov's energy flux density and the charge field energy density.

We write the expression for the relativistic pulse of electromagnetic mass:

$$\mathbf{P}_e = \int \frac{\mathbf{S}_u}{c^2} dV = \int \frac{q\varphi_0\mathbf{v}}{2c^2\sqrt{1-(v/c)^2}} dV = \frac{m_e\mathbf{v}}{\sqrt{1-(v/c)^2}}. \quad (5.10)$$

It is easy to see that the obtained expression (5.10) corresponds to the classical expression with accuracy up to a relativistic factor. The problem of electromagnetic mass has received a strict solution.

Now we can make ***an important conclusion for physics***. Maxwell electrodynamics has two branches. The first branch (retarded potentials) describes wave processes. The second branch (instantaneous action at a distance) describes the quasi-static phenomena of electrodynamics. Fields of charges  $\mathbf{E}$  and  $\mathbf{H}$  are instantaneous fields. The magnetic field  $\mathbf{H}$  is the result of the movement of the charge. The fields  $\mathbf{E}$  and  $\mathbf{H}$  of an electromagnetic wave are interconnected and cannot exist separately. These fields spread at the speed of light.

## 6. Physical Ether Against Material Ether

Now we need to describe the supposed nature of instantaneous action at a distance and the reason for the constancy of the speed of light in any inertial reference system. This question requires the introduction of a hypothesis. In materialist philosophy, there is no such term as "absolutely empty space". Such an idea of "emptiness" is a ***mathematical abstraction***. The whole space is filled with "physical ether." This is a new hypothesis, which is not in modern physics. We must describe the properties of the ***physical ether*** and show its fundamental difference from other models of "ethers" proposed by physicists.

Let us start with the laws of mechanics for conservative systems:

- 1) The equation of motion of the body is invariant with respect to the Galilean transformation. This means that the force acting on the body and the acceleration acquired by the body are also invariant with respect to the Galilean transformation.
- 2) The law of conservation of momentum is invariant with respect to the Galilean transformation.
- 3) The law of conservation of angular momentum is invariant with respect to the Galilean transformation.
- 4) The law of conservation of energy is invariant with respect to the Galilean transformation.
- 5) The invariance of the speed of light in different inertial reference systems should be added. We will discuss this fact specifically later.

If we take into account that the ether is *a kind of intermediary* in the interaction of charges, currents, gravitational masses, then the following properties of the ether, which we call the *physical ether*, are revealed:

- 1) The properties of the physical ether are the same in all inertial reference systems, i.e. are invariant. In any inertial reference system, the physical ether has the same properties! This fact is the main difference between the physical ether model and all other ether models, similar to material media.
- 2) The main property of the physical ether is its lack of an absolute reference system. Material models of “ethers” necessarily have an absolute reference system in which the ether is stationary. This is their fundamental difference from the physical ether.
- 3) Physical ether has linear properties. Ether does not affect the fields, waves and their interaction with each other. However, it can play the role of a mediator in the interaction of material objects and in the propagation of oscillations. Interactions like “photon-photon” in the physical ether are impossible.
- 4) The physical ether has no inertia. It has neither mass density, nor impulse density, nor density of any energy.
- 5) Physical ether does not resist the movement of neutral material bodies and does not possess viscosity.
- 6) Physical ether is an intermediary for instantaneous action at a distance (in the interaction of inertial charges). Ether transmits the effects of objects on each other, although it does not participate in the process of energy exchange and the exchange of pulses.
- 7) Electromagnetic waves are waves of ether oscillations in physical space. Since the properties of the physical ether do not depend on the choice of the inertial reference system, the propagation velocity of these oscillations is unchanged. It is the same in any inertial reference system.

We have described some properties of the physical ether that help us understand the cause of instantaneous action at a distance and the cause of the constancy of the speed of light. There are models of *material ether* (analogue of *material media*). Their main disadvantage is that the material models have *an absolute reference system*, i.e. they contradict the equivalence principle of Galileo-Poincaré inertial systems.

## 7. Charge Field and Instant Action at a Distance

Let us turn to the quasi-static branch of classical electrodynamics. A resting body creates an electrostatic field around itself. The field is a figurative physical *model* (reflection of a fragment of reality), which allows us to give a speculative idea and, based on *analogy*, present a picture of physical phenomena and processes. According to modern concepts of quasi-static electrodynamics, the electric charge is surrounded by *vacuum* (emptiness). It is impossible to imagine a carrier that would create in the surrounding charge of an *absolutely empty* space something *material*, for example, a field.

Physical ether saves the situation. From the above point of view, the charge forms (relatively speaking) around itself from the ether something like *an infinite continuous medium*. This condition of the ether we call the electric field of a fixed charge. The charge field is the excited state of the physical ether generated by the charge. The charge field has *energy* and *strength*

properties. It can affect other charges with some force and cause their acceleration. The ether here is only an *intermediary*.

Consider the charge field and give some definitions:

**Definition 1.** *The electric field potential at a given point in space*, created by an electric charge resting in this inertial reference frame, is an **energy** characteristic of the rest charge field. The potential is numerically equal to the work that we must do in order to move the trial (unit, positive, point) charge from infinity to a given point in space.

**Definition 2.** *The electric field strength of a fixed charge at some point in space is a force* characteristic of the field. It is numerically equal to the force that will act on the test (unit, positive, point) charge **resting** at a given point in space.

We can **conditionally** consider the charge field (potential and intensity) as a certain *infinite medium* surrounding the charge (excited state of the ether). Potential theory often uses the concept of a *point charge*. This is a charged body, which in the conditions of the physical problem under consideration has a *negligibly small size*. Note that the charged body of “point size” has a finite inertial mass of rest and the magnitude of the electric charge.

In physics and in the theory of potential, there is a *law of charge conservation*. Point charge does not disappear and does not occur. The charge is stable and does not fall apart. If the charge moves with the speed  $\mathbf{v}$ , then  $\text{div } \mathbf{v} = 0$ . In addition, if a *point* charged body *rotates around its axis*, around it **there is no rotation** of the scalar potential ( $\text{rot } \mathbf{v} = 0$ ) and, accordingly, there is no magnetic field.

This is evidence of an important fact. When a charge moves, its field moves only **translationally**, regardless of the nature and curvature of the trajectory. The field moves parallel to itself. This unusual property of the motion of a point charge field is precisely due to the properties of the physical ether surrounding the charge. All potential points simultaneously have *the same velocity vector*, regardless of the trajectory of the charge. The charge potential (physical ether) does not perform a *rotational* motion relative to its center of mass. Recall that the scalar potential of a charged body satisfies the Poisson equation:

$$\Delta\varphi = -\frac{\rho}{\varepsilon}. \quad (7.1a)$$

**The continuity equation for scalar potential.** Considering the conditionally scalar potential of a charge as some *continuous medium* (the state of a physical ether), we can use for the charge field the ratios obtained in continuum mechanics. For example, the continuity equation for a scalar potential has the standard form:

$$\frac{\partial\varphi}{\partial t} + \text{div } \mathbf{v}\varphi = 0. \quad (7.1)$$

This is the well-known equation of continuum mechanics. We can now introduce the vector potential. Let  $\mathbf{A} = \varphi\mathbf{v}/c^2$ , then we get a new form of the continuity equation:

$$\frac{1}{c^2} \frac{\partial\varphi}{\partial t} + \text{div } \mathbf{A} = 0. \quad (7.2)$$

In electrodynamics, this condition is usually called the Lorentz gauge condition. We recall that the potential of the field of a point charge always moves translationally, i.e. all points of the potential  $\varphi$  have the same speed.

Again, we return to the charge-excited physical ether, as a conditional “medium”, and the laws of continuum mechanics.

**The conservation equation for vector tubes.** In continuum mechanics there is a continuity equation for some arbitrary vector  $\mathbf{a}$ . The vector  $\mathbf{a}$  describes the infinite vector field created by the field source. This field has an instantaneous character, like a scalar potential.

The equation of the persistence of vector tubes is:

$$\frac{\partial \mathbf{a}}{\partial t} + \mathbf{v} \operatorname{div} \mathbf{a} + \operatorname{rot}[\mathbf{a} \times \mathbf{v}] = 0. \quad (7.3)$$

If we replace vector  $\mathbf{a}$  with the vector Coulomb field  $\mathbf{E}_q = -\operatorname{grad} \varphi$ , then we can write:

$$\begin{aligned} \frac{\partial \operatorname{grad} \varphi}{\partial t} + \mathbf{v} \operatorname{div} \operatorname{grad} \varphi + \operatorname{rot}[\operatorname{grad} \varphi \times \mathbf{v}] &= \frac{\partial \operatorname{grad} \varphi}{\partial t} + \mathbf{v} \Delta \varphi + \operatorname{rot}(\varphi \mathbf{v}) \\ &= 0. \end{aligned} \quad (7.4)$$

**A third-party electric field** (Faraday field). When a scalar potential moves with respect to a fixed observer, the observer will find an “additive” to the field strength. This additive is a **third-party electric field** of Faraday. The intensity of the external field is equal to:

$$\mathbf{E}_F = -\frac{\partial \mathbf{A}}{\partial t}. \quad (7.5)$$

This field is third-party because it cannot be expressed in the form of the potential gradient of the electrostatic field  $\mathbf{E}_q$ , i.e. The  $\mathbf{E}_F$  field is *not of electrostatic origin*. The third-party EMF is the result of the movement of the scalar potential field relative to the resting test charge in the observer’s reference frame. It is easy to show that the identity holds:

$$\operatorname{rot} \mathbf{E}_F = -\mu \operatorname{rot} \frac{\partial \mathbf{A}}{\partial t} = -\mu \frac{\partial \mathbf{H}}{\partial t}. \quad (7.6)$$

This identity is called the “Faraday’s Law”.

If Maxwell followed the laws of potential theory and continuum mechanics, he would write the following system of equations:

$$\left. \begin{aligned} \operatorname{rot} \mathbf{H} &= \varepsilon \frac{\partial \mathbf{E}_q}{\partial t} + \mathbf{j} \\ \operatorname{rot} \mathbf{E}_F &= -\mu \frac{\partial \mathbf{H}}{\partial t} \\ \operatorname{div} \mathbf{E}_q &= -\frac{1}{\varepsilon} \Delta \varphi = -\frac{\rho}{\varepsilon} \\ \operatorname{div} \mathbf{H} &= 0 \end{aligned} \right\}, \quad (7.7)$$

Where

$$\mathbf{H} = \frac{1}{\mu} \operatorname{rot} \mathbf{A}, \quad \mathbf{E}_q = -\operatorname{grad} \varphi, \quad \mathbf{E}_F = -\frac{\partial \mathbf{A}}{\partial t}, \quad \mathbf{j} = \rho \mathbf{v}. \quad (7.7a)$$

The system of equations (7.7) perfectly describes quasi-static phenomena. All fields and potentials are instantaneous. So, we consider the instantaneous charge field as a continuous medium (perturbation of the physical ether), which is well described in the framework of continuum mechanics.

It is interesting to note the following circumstance. Maxwell believed that the electric field is one. He did not distinguish between Coulomb and Faraday electric fields. If we remove the indices with electric fields and combine the electric fields, then the system of equations (7.7) takes the standard form of writing Maxwell's equations:

$$\left. \begin{aligned} \operatorname{rot} \mathbf{H} &= \varepsilon \frac{\partial \mathbf{E}}{\partial t} + \mathbf{j} \\ \operatorname{rot} \mathbf{E} &= -\mu \frac{\partial \mathbf{H}}{\partial t} \\ \operatorname{div} \mathbf{E} &= -\frac{1}{\varepsilon} \Delta \varphi = -\frac{\rho}{\varepsilon} \\ \operatorname{div} \mathbf{H} &= 0 \end{aligned} \right\}, \quad (7.8)$$

Where

$$\mathbf{H} = \frac{1}{\mu} \operatorname{rot} \mathbf{A}, \quad \mathbf{E} = -\operatorname{grad} \varphi - \frac{\partial \mathbf{A}}{\partial t}, \quad \mathbf{j} = \rho \mathbf{v}. \quad (7.8a)$$

We will not analyze here the connection of equations (7.7) and (7.8). This is a special topic affecting the wave branch of electrodynamics. We will give only a brief explanation concerning the Coulomb interaction of charges.

## 8. Charge field and Lorentz transformation

In Section 5, we proved Umov's conservation law for charge fields and solved the relativistic problem of electromagnetic mass. We found that instantaneous potentials may be present in solutions of Maxwell's equations. In other words, it is possible to set such conditions under which the solution of the system of Maxwell equations will contain instantaneous potentials.

This is convenient to show if we write down the potentials of the Maxwell equation in the form of 4-potentials.

$$\frac{\partial^2 A_i}{\partial x_k^2} = -\mu j_i, \quad (5.1)$$

$$\frac{\partial A_i}{\partial x_i} = 0, \quad (5.2)$$

$$\frac{\partial j_i}{\partial x_i} = 0, \quad (5.3)$$

Where

$$j_i = cq u_i, \quad A_i = \frac{\varphi u_i}{c}, \quad u_i = \frac{dx_i}{ds}. \quad (5.3a)$$

In Section 5, we proved Umov's conservation law for charge fields and solved the relativistic problem of electromagnetic mass. We found that instantaneous potentials may be present in solutions of Maxwell's equations. In other words, it is possible to set such conditions under which the solution of the system of Maxwell equations will contain instantaneous potentials. This is convenient to show if we write down the potentials of the Maxwell equation in the form of 4-potentials. Maxwell's equations are described by the expression (5.1); Lorentz gauge condition by expression (5.2); continuity equation for 4-current vector by (5.3). This is a standard relativistic recording of Maxwell's equations used in many textbooks.

We will be interested in two expressions: condition (5.2) and 4-vector  $A_i$ . Classical analogues of these expressions have the form:

$$\operatorname{div} \mathbf{A}_0 + \frac{1}{c^2} \frac{\partial \varphi_0}{\partial t} = 0, \quad (8.1)$$

$$\mathbf{A}_0 = \frac{\varphi_0}{c^2}. \quad (8.2)$$

We will assign the instantaneous potentials index "0". The expression (8.2) fixes the "hard link" between the scalar and vector potentials. Recall that the instantaneous scalar potential is able to make only translational (rectilinear or curvilinear) motion in space. It is easy to verify that by substituting expression (8.2) into the Lorentz gauge condition (8.1), we obtain the continuity equation for the scalar potential  $\varphi_0$ .

$$c^2 \operatorname{div} \mathbf{A}_0 + \frac{\partial \varphi_0}{\partial t} = \operatorname{div} \mathbf{v}_0 + \frac{\partial \varphi_0}{\partial t} = 0 \quad \text{or} \quad \frac{\partial \varphi_0}{\partial t} = -\operatorname{div} \mathbf{v}_0. \quad (8.3)$$

Now we can eliminate partial derivatives from Maxwell's equations. For illustration, we consider the scalar potential of a point inertial charge, which moves along the  $x$ -axis with a velocity  $\mathbf{v}$ . Using (8.3), one can find the following expressions when moving along the  $x$ -axis:

$$\left. \begin{aligned} \frac{\partial^2 \varphi_0}{\partial t^2} &= -\frac{\partial \varphi_0}{\partial t} \left( v \frac{\partial \varphi_0}{\partial x} \right) = -v \frac{\partial}{\partial x} \frac{\partial \varphi_0}{\partial t} - \frac{\partial \varphi_0}{\partial x} \frac{\partial v}{\partial t} = v^2 \frac{\partial^2 \varphi_0}{\partial x^2} - \frac{\partial \varphi_0}{\partial x} \frac{\partial v}{\partial t}, \\ \frac{\partial \varphi_0}{\partial t} &= -\operatorname{div} \mathbf{v} \varphi_0 = -v \frac{\partial \varphi_0}{\partial x}. \end{aligned} \right\} \quad (8.4)$$

If the charge moves at a constant speed  $\mathbf{v}$ , then expression (8.4) can be simplified

$$\frac{\partial^2 \varphi_0}{\partial t^2} = v^2 \frac{\partial^2 \varphi_0}{\partial x^2}. \quad (8.5)$$

Using (8.5), we reduce the *wave equation* for the scalar potential to an equation of Poisson (*elliptic*) type

$$\left( 1 - \frac{v^2}{c^2} \right) \frac{\partial^2 \varphi_0}{\partial x^2} + \frac{\partial^2 \varphi_0}{\partial y^2} + \frac{\partial^2 \varphi_0}{\partial z^2} = \frac{q}{4\pi\epsilon a^2 \sqrt{1 - \frac{v^2}{c^2}}} \delta(x - vt, y, z), \quad (8.6)$$

where  $a$  is the radius of the sphere over which the charge is distributed. The solution of equation (8.6) is the scalar potential  $\varphi_0$ :

$$\varphi_0 = \frac{q}{4\pi\epsilon \sqrt{(x - vt)^2 + \left(1 - \frac{v^2}{c^2}\right)(y^2 + z^2)}}. \quad (8.7)$$

This potential  $\varphi_0$  is instantaneous. We pay attention to the fact that expression (8.7) we can get in another way. We can, for example, apply the Lorentz transformation to the potential of a resting charge. Similar expressions can be obtained for the vector potential  $\mathbf{A}_0$ .

So instantaneous potentials can be transformed using the Lorentz transform. Instant action at a distance does not contradict this transformation.

**The speed of propagation of interactions.** This concept was introduced by Einstein. He relied on the Lorentz transformation, which included the multiplier  $1/\sqrt{1 - \frac{v^2}{c^2}}$ . Einstein's "postulate" is not correct for the following reasons. The attribute of pairwise interaction is direct or indirect (through the fields) *contact* of interacting objects:

- 1) If there is no contact, there is no interaction.
- 2) The contact area belongs to both interacting objects simultaneously.
- 3) Consequently, the term "the speed of propagation of interactions" does not belong to one of the interacting objects, but precisely this area. If there is no contact, then there is no interaction and it is meaningless to talk about the speed of its spread.

The term "the speed of propagation of interactions" is an *emotional*, but not a scientific concept. Therefore, in the textbooks you will find a lot of attempts to illustrate the postulate, but you will not find any strict definition of this concept.

We will give a new definition of Einstein's idea:

***In the framework of the Lorentz transformation, the speed of movement of inertial systems, physical objects, material media and instantaneous potentials cannot exceed the speed of light.***

So, the instantaneous potential and the Lorentz transformation do not have contradictions.

## 9. LAGRANGIAN of Interaction of Electric Charges

The state of the physical ether excited by a charge is a mediator, as we said, with instantaneous action at a distance. The physical ether does not possess inertia, all changes in free space occur instantly. Any new charge, falling into the electric field of the first, instantly feels the effect of force. At the same time, the first charge experiences the same effect from the second. The mediator of interaction is not “*emptiness*”, as it is written in modern physics, but the state of the ether excited by charges. Due to the symmetry of the interaction, the ether does not change its energy. It provides the interaction between the charges simultaneously in both directions.

As is known, the interaction of two charges can be described using the following Lagrange function:

$$L_{\text{int}} = e_1 c u_i^{(1)} A_i^{(2)} = e_1 c u_i^{(1)} \varphi_2 u_i^{(2)} \approx \frac{e_1 e_2}{4\pi\epsilon R_{12}} u_i^{(1)} u_i^{(2)}. \quad (9.1)$$

The expression  $u_i^{(1)} u_i^{(2)}$  is a true scalar:

$$u_i^{(1)} u_i^{(2)} c^2 = \frac{(ic, \mathbf{v}_1)}{\sqrt{1 - \frac{v^2}{c^2}}} \cdot \frac{(ic, \mathbf{v}_2)}{\sqrt{1 - \frac{v^2}{c^2}}}. \quad (9.1a)$$

So, in the non-relativistic approximation ( $v \ll c$ ) we have:

$$L_{\text{int}} = \frac{e_1 e_2}{4\pi\epsilon R_{12}} u_i^{(1)} u_i^{(2)} \approx -\frac{e_1 e_2}{4\pi\epsilon R_{12}} \left( 1 + \frac{(\mathbf{v}_1 - \mathbf{v}_2)^2}{2c^2} \right). \quad (9.2)$$

Note that expression (9.2) was obtained by us without hypotheses. It is invariant with respect to the Galilean transformation and makes it possible to give a simple explanation of the existing magnetic paradoxes. Some of the paradoxes are considered in [10].

Using (9.2) it is easy to write the Hamilton function for two charges. It will be

$$H = \frac{m_1 \mathbf{v}_1^2}{2} + \frac{m_2 \mathbf{v}_2^2}{2} + \frac{e_1 e_2}{4\pi\epsilon R_{12}} \left( 1 + \frac{(\mathbf{v}_1 - \mathbf{v}_2)^2}{2c^2} \right). \quad (9.3)$$

In modern electrodynamics, which rejects the instantaneous action at a distance, there are great difficulties not only in writing the nonrelativistic Hamiltonian function, but in explaining “the

predicted phenomena” (magnetic paradoxes). For example, in [11], the authors introduce the following Hamilton non-relativistic function:

$$H = \frac{(\mathbf{P} - e\mathbf{A})^2}{2m} + e\varphi, \quad (9.4)$$

Where

$$\mathbf{P} = m\mathbf{v} + e\mathbf{A} \quad (9.5)$$

is a fictitious momentum. If we substitute (9.5) into (9.4), we obtain:

$$H = \frac{m\mathbf{v}^2}{2} + e\varphi. \quad (9.6)$$

The vector potential in expression (9.4) is actually absent. It disappeared! This means that the Hamiltonian function (9.4) is not capable of describing the magnetic interaction of charges. Hamilton’s function (9.4) is a mathematical forgery, falsification. It is made to hide problems and get away from the need to solve them. Such a step creates the illusion of the right decision. Falsification creates new paradoxes and problems.

## 10. Gravitation as A Quadratic Quasi-Static Effect

In the Introduction, we mentioned Thomson’s interesting hypothesis about the electromagnetic nature of gravity. At present, physicists are working on the A. Einstein GTR. The fantastic implications of this theory (The “Big Bang Theory”, “Black Holes”, “Dark Matter”, and others) are misleading and questioned by many researchers.

We analyzed the mathematical foundations of GR and found out an interesting fact. It turns out that 200 years ago geometers made a mistake. They decided that curved space can exist independently. As shown in [12] Curvilinear space cannot exist on its own! This space can only be defined in Euclidean space. If the Euclidean space “disappears”, then the curvilinear space will automatically disappear. For this reason, one cannot consider GTR as a scientific theory. The physical interpretation of gravitational phenomena in GR is incorrect. The analysis showed that Thomson’s idea of the electromagnetic nature of gravity is easily realized in the framework of the quasi-static branch of classical electrodynamics [13]. The idea of the solution is as follows. In nonrelativistic mechanics, there are two concepts of mass: the first refers to the second law of Newton, and the second to the law of universal gravitation.

*The first mass – inert (or inertial) – is the ratio of non-gravitational force acting on the body to its acceleration.*

*The second mass – gravitational – determines the force of attraction of the body by other bodies and its own force of attraction.*

***These two masses are measured in different experiments, therefore they are absolutely not obliged to be connected, and even more so – equivalent to each other.***

Moreover, recognition of *quantitative* equality (or proportionality) implies inevitable *qualitative* equivalence, i.e. mass identity. From a physical point of view, this is unacceptable.

Now we show the new path. If we write the Lagrange function for the interaction of two protons (3.3), adding to it quadratic terms, then we get:

$$L_q = -\frac{1}{4\pi\epsilon R_{12}} q_1 q_2 + \frac{1}{R_{12}} k(q_1 q_2)^2 + \dots, \quad (10.1)$$

where  $q_1, q_2$  are magnitudes of interacting charges,  $R_{12}$  is the relative distance between charges,  $k$  is a coefficient of proportionality.

The second term of the sum in brackets in expression (10.1) is very similar to the Lagrange function for the law of universal gravitation:

$$L_g = G \frac{m_1 m_2}{R_{12}}. \quad (10.2)$$

If we assume that the gravitational charge (*gravitational* mass  $m$ ) is proportional to the square of the electric charge

$$m_i = \sqrt{\frac{k}{G}} q_i^2, \quad (10.3)$$

Then we get the Lagrange function for the law of universal gravitation (10.2).

We will not consider here the interesting consequences of the new approach. They are described in [13]. Solving the “4/3” problem opens the way for new research directions. Firstly, the existing ideas about tensor gravitational waves are erroneous. Gravitational waves can be longitudinal, transverse, etc. Secondly, there is an interesting problem of detecting anti-gravity, etc.

## 11. Conclusion

Errors that scientists do not correct in time, turn into prejudices that hinder the development of science. One of these prejudices was the “4/3 problem” or the electromagnetic mass problem. So, we showed the following;

- 1) The problem of electromagnetic mass has a strict solution only if the fields are instantaneous. This result is valid in both the classical and relativistic variants.
- 2) We introduced the hypothesis of the existence of a physical ether. The properties of the physical ether do not depend on the choice of the inertial reference system. The physical ether allows us to explain the constancy of the speed of light in inertial reference systems and features of instantaneous action at a distance.
- 3) Errors in the non-relativistic Lagrange function were revealed. The corrected version of the Lagrange function for the interacting charges is invariant with respect to the Galilean

transformation and allows one to resolve the magnetic paradoxes that have arisen in physics earlier.

- 4) We have shown that the phenomena of gravity can be regarded as quadratic effects of quasi-static electrodynamics.

The results are not limited to electrodynamics. They allow, for example, to give a correct explanation of “quantum entanglement”, etc. However, the discussion of such problems is beyond the scope of this article.

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