

Reynolds Number in Electrodynamics

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Abstract

The electric charge definition is formulated. The refined formula of the electric charge non-invariance is given. The electric charge momentum conservation law was obtained. The concept of "the charged particle spin" is clarified. The angular momentum conservation law for electric charge was obtained. The frequency moment definition (the magnetic moment analog) is formulated in gravidynamics. The formula for the kinetic energy of the translational motion of an electric charge was constructed. Steiner's theorem for electrodynamics was formulated. The rotational motion dynamics equation was constructed for electric charge. The formula for the kinetic energy of the rotational motion of an electric charge was constructed. A Planck formula analog for the magnetic field was obtained. Formula for the interval s between two events was constructed in the electric charge space. The author proposes the Coulomb's law application limit explanation. A parallel study possibility justification of black holes and atomic nuclei is given. A Reynolds number analog for electromagnetism was obtained: $\dot{R} = \rho e v D/H = I D/(s H) = 4I/(\pi D H)$. The experiments result on finding the Reynolds number in electro-dynamics are given.

Keywords

The Angular Momentum of Electric Charge, The Rotational Motion Dynamics Equation for Electric Charge, A Planck Formula for the Magnetic Field, Reynolds Number in Electrodynamics

Introduction

Electric charge is a body acceleration measure when only an electric field is applied to the body (it's assumed that the body consists only of an electric charge, that's it hasn't mass).

To unambiguous interpret of the terms used in this work the author considers it necessary to make some remarks about terminology. Just as in the electric charges interaction field there are electric, magnetic, and electromagnetic fields, in the masses interaction field there are gravitational, frequency (the author suggests using this term) and gravifrequency (again, the author suggests using this term) fields. The term "gravitational field" is used in the conventional sense (field with a strength a , which is the acceleration). The frequency field is the field of the angular velocity ω . The term "angular velocity field" may be replaced with the term "frequency field". And the gravifrequency field is the same set of gravitational and frequency fields as the electromagnetic field is the set of electric and magnetic fields. It would be more accurate to speak of a gravifrequency field

equations system but not of the gravitational field equations system, and not of gravitational waves, but of gravifrequency waves.

After Maxwell's electrodynamics united in one theoretical scheme the phenomena of electricity, magnetism, and optics on the electromagnetic field concept basis, it was hoped that the field concept should be the foundation of a future unified theory of the physical world [1].

Einstein attempted to construct a unified field theory in which gravitational and electromagnetic fields are interpreted only as components or manifestations of the same unified field [2].

The author believes that there is some set of similar formulas (but not identical) that allows you to describe the phenomena of electrodynamics and gravidynamics. Subsequently, it will probably be possible to add hydrodynamics, thermodynamics, and other sections of physics. But the same structure of these

formulas (and the symbols included in them) will imply completely different physical quantities, characteristic of one or another section of physics.

According to Okun L. B. the simplest variants realizing the idea of grand unification assume that there are no new fundamental forces up to colossal energies of the order of 10^{15} GeV [3].

This work considers the frequency interaction, which is a new fundamental interaction.

Formulation of the Problem

The purpose of this work is to generalize and specify some concepts of electrodynamics and gravodynamics, as well as to present the results of experiments to determine of the Reynolds number in elec-trodynamics.

Results

- the momentum conservation law and the angular momentum conservation law are formulated for electric charge;
- the concept of "the charged particle spin" is clarified;
- Steiner's theorem for electrodynamics was formulated;
- the Planck formula analog was obtained for the magnetic field;
- formula for the intervals between two events was constructed in the electric charge space;
- the rotational motion dynamics equation was constructed for electric charge;
- the Reynolds number analog values were experimentally obtained in the current range from 20 mA to 500 mA.

Discussion

Electric Charge, Electric Charge Non-invariance, Charged Particle Spin, Frequency Moment

The Lagrange function L for the electric charge e in the electromag-netic field can be written in the form [4].

$$L = -mc^2 \sqrt{1 - \frac{v^2}{c^2}} + e(\mathbf{A} \cdot \mathbf{v}) - e\phi \quad (1)$$

Let's transform the Lagrange function for the electric charge space.

By the concept of "electric charge space" the author understands everything that exists or happens without the presence of masses.

That's all bodies must be of zero mass and processes or phenomena must occur with bodies having zero mass.

Since in gravifrequency interactions the vector potential $A_g = v$, [7], and $v = a \times t$,

then in electric charge space

$$A_e = E \times t,$$

where E is electric field strength.

And when the vector potential A_e is multiplied by the electric charge e, the formula for the electric charge momentum p_e is formed.

$$p_e = e A_e$$

It should be noted that p_e is not a part of the fictitious momentum P, as indicated in the work [5], but of the real one. There is

no fiction here. The electric charge momentum p_e is a part; of the generalized momentum P, which is equal to the sum of the mechanical momentum (mv) and of the electric charge momentum (p_e). And hence, there is no forgery or falsification here.

In work [6], it is stated: Newton's law of world gravitation has not yet had an electromagnetic explanation. It should be noted that it and cannot receive an electromagnetic explanation. Our knowledge of mass and electric charge (as well as mass and electric charge themselves) goes parallel streets. The kind of laws on one street coincide with the kind of laws on the other street. But the basis on each street is different, on one street it is mass and on the other street it is electric charge. Therefore, it is incorrect to explain any effects of gravitation (not only the Newton's law of world gravitation) with the help of electric charge. How can a tomato salad have a cucumber explanation?

It's impossible to explain mass through electric charge and vice versa. Gravifrequency phenomena are explained by the presence and motion of masses, and electromagnetic phenomena are explained by the presence and motion of electric charges.

For the electric charge space (given that $E = \lambda e$ [8], and $c^2 \leftrightarrow \lambda$ [12], the Lagrange function will be in the form

$$L_e = -e\lambda \sqrt{1 - \frac{\mathbf{E}t\mathbf{v}}{\lambda}} + e(\mathbf{A}_e \cdot \mathbf{v}) - e\phi_e \quad (2)$$

where λ is constant, $\lambda \approx 10^6$ V [8];

ϕ_e is electric field potential.

The refined formula of electric charge non-invariance was applied in formula (2), [8].

$$e = \frac{e_0}{\sqrt{1 - \frac{\mathbf{E}t\mathbf{v}}{\lambda}}}$$

Then the action Se for an electric charge in an electromagnetic field can be written as follows

$$S_e = \int_{t_1}^{t_2} (-e\lambda \sqrt{1 - \frac{\mathbf{E}t\mathbf{v}}{\lambda}} + e(\mathbf{A}_e \cdot \mathbf{v}) - e\phi_e) dt$$

Let's write the expression for the electric charge momentum p_e located in a constant electric field with strength $E = (E_x, 0, 0)$. Notice the body is in the electric charge space.

$$p_e = e E t,$$

where t is the existence time of the body in the electric field. There is the electric field only.

Then we can write an expression for the force $\frac{d\mathbf{p}_e}{dt} = \mathbf{F}_e$,

where $F_e = e E$.

In the absence of external forces ($F_e = 0$) we can write

$$\frac{d\mathbf{p}_e}{dt} = \mathbf{0}$$

It's possible to formulate the electric charge momentum conservation law: the electric charge momentum (located in a system of electric charges) is constant for a closed system.

It should be noted that the electron spin needs to be specified. The electron has mass and electric charge. Each of these quantities is responsible for its part (its contribution) to the total spin. And since both parts are measured in the same units (J·s), they appear as one common spin.

This remark about spin applies to all particles that have mass and electric charge.

The same can be said about the orbital momentum (mechanical and electric) of objects that have a mass and electric charge. The total momentum will consist of the sum of the mechanical momentum (mv) and the electric charge momentum (e E t).

Let's compare the expressions for the momentum of the electron in an atom as the possessor of mass and as the possessor of electric charge [7].

$$mv/(eEt) \quad (3)$$

Given that $v = at$, we can rewrite the previous expression as $mat/(eEt) = ma/(eE)$

In the right part of the equation, we see the relation of two forces: centripetal and Coulomb forces. In the problem under consideration, they are equal when moving in a circle. So, the relation (3) is equal to 1. Consequently, the mechanical momentum (mv) is equal to the electric momentum (eEt). And hence the momentum of mechanical momentum (mvr) is equal to the momentum of electrical momentum (eEtr).

Then, comparing mechanical kinetic energy ($mv^2/2$) and electric kinetic energy ($eEtv/2$) we can see that they are equal. This statement is more truer than in previous works.

By analogy with mechanics let's write the expression for the point electric charge e angular momentum L_e (in the electric charge space) relatively to the point O as a vector product $L_e = [r \times p_e]$,

where r is the radius vector from point O to the point charge e. $L_e = e [r \times E] t$

$$\frac{dL_e}{dt} = [r \times F_e]$$

$$\frac{dL_e}{dt} = M_e,$$

And we got the expression for the force's moment M_e relatively to the same point O.

It's possible to formulate the angular momentum conservation law for electric charge: the electric charge angular momentum L_e is constant for a closed system (that's $M_e = 0$).

Let's find a physical quantity that is the magnetic moment analog p_m . Let's write down the formula for the magnetic moment p_m $p_m = ISn$.

By analogy with the electric charge space, let's call the next expression the frequency moment p_ω $p_\omega = I_{mas} S n$,

where I_{mas} is mass current flowing along the circuit; S is the area covered by this contour.

The mass current I_{mas} should be understood as the consumption Q_{mas} of mass m, that's the mass m change per unit time t $I_{mas} = Q_{mas} = \Delta m / \Delta t$

Kinetic Energy and Steiner Theorem for Electric Charge

By analogy with mechanics, we can write an expression for kinetic energy E_k of the translational motion of an electric charge e

$$E_{ke} = e \times E \times t \times v / 2$$

(understanding that $E \times t$ is an analog of $a \times t = v$) We can write a general expression for the kinetic energy

$$E_k = pv/2$$

If the body has both mass and electric charge, the total kinetic energy will be as follows

$$E_k = E_{kg} + E_{ke} = p_g v/2 + p_e v/2 = mvv/2 + eEtv/2 = (mv + eEt)v/2 = pv/2$$

And not only mass, but also the electric charge of the body (particle) is responsible for the amount of energy in the body (particle).

And when calculation the total energy E_{tot} of a body (particle) it will be necessary to take into account the formula [8].

$$E = e\lambda$$

By analogy with mechanics, we define the electric charge e inertia moment I_e relatively to a given axis as the value equal to the product of the electric charge e and the distance r square to the considered axis

$$I_e = e r^2$$

It's possible to formulate the Steiner theorem analog (for electric charge). The electric charge e inertia moment I_e relatively to an arbitrary axis is equal to its moment I_c of inertia relatively to a parallel axis passing through the electric charge center C added with the product of the electric charge e and the distance a square between the axes

$$I_e = I_c + e a^2 \quad (4)$$

In mechanics $L = I \omega$,

where L is the angular momentum;

I is the inertia moment;

ω is the angular velocity.

Passing to the electric charge space, we replace ω by magnetic induction B/2 [7].

By analogy we can write

$$L_e = I_e B/2$$

where L_e is the angular momentum of the electric charge. It's possible to construct the rotational motion dynamics equation of electric charge e relatively to a fixed axis.

In mechanics [9].

$$\mathbf{M} = I \frac{d\boldsymbol{\omega}}{dt},$$

where M is the force moment.

Passing to the electric charge space, we can write the rotational motion dynamics equation of electric charge

$$\mathbf{M}_e = \frac{1}{2} I_e \frac{d\mathbf{B}}{dt},$$

where $\mathbf{M}_e = [\mathbf{r} \times \mathbf{F}_e] = [\mathbf{r} \times (e \mathbf{E} + e \mathbf{v} \times \mathbf{B})]$

It's possible to construct a formula for the kinetic energy of the rotational motion in the electric charge space. The kinetic energy of the rotational motion in mechanics is calculated by the formula

$$E_k = I \omega^2 / 2$$

By analogy let's write down the formula for the kinetic energy E_{ke} of the rotational motion in electric charge space. In the last formula we replace ω by $B/2$ (but only for one ω). Then

$$E_{ke} = I_e \omega \cdot B / 4$$

Planck Formula, Interval, Uncertainty Ratio

In the electric charge space, it's possible to construct the Planck formula analog, in which the magnetic induction B will participate together with some constant. Let's write down the Planck formula

$$E = \hbar \omega$$

Let's replace ω with the magnetic induction B. In this case, it will be necessary to replace \hbar with another constant

$$E = \text{const} \times B/2$$

From this it can be seen that if \hbar represents a certain value of the angular momentum in the Planck formula, then the constant represents a certain (constant) minimum value of the magnetic moment in the last formula. Let's denote it by p_{m0} . It's highly likely that it will be the nuclear magneton.

Then

$$E = p_{m0} \cdot B$$

This is the Planck formula analog.

There is a formula for the interval s between two events [10].

$$s^2 = c^2 t^2 - x^2 - y^2 - z^2$$

Let's construct this formula analog in the electric charge space. c^2 will be replaced by λ . In the expression t^2 we pass to angular velocity ($t = 2\pi/\omega$). And we will do it only for one time, and leave the second time t unchanged.

In the right-hand side of the equation, the first term will look like this $\lambda t \cdot 2\pi / \omega$. And now we replace ω by $B/2$. And we get the final formula for the interval se between two events in the electric charge space

$$s_e^2 = \lambda t (4\pi/B) - x^2 - y^2 - z^2$$

De Broglie wavelength $\lambda_b = h/p$ [10]; In the electric charge space, it will look as follows

$$\lambda_{Be} = h/(eEt);$$

$$\lambda_{Be} / (2\pi) = \hbar/(eEt);$$

$$1/k_e = \hbar/(eEt)$$

$$eEt = \hbar k_e$$

$$p_e = \hbar k_e$$

Let's write the uncertainty ratio [10],

$$\Delta E \times \Delta t \geq \hbar$$

Considering that [8],

$$E = e \lambda,$$

we can write

$$\Delta(E \lambda) \times \Delta T \geq \hbar$$

$$\Delta E \times \Delta T \geq \hbar / \lambda$$

The shorter some state existence time or the time allotted for its observation, the less definitively it's possible to speak about the electric charge of this state.

Let's think about the uncertainty ratio from a different point of view. Based on the three conservation laws (angular momentum, energy and momentum), we can formulate three postulates.

a) **Postulate 1:** there is a minimum value of angular momentum (it turned out to be equal to \hbar).

This follows the Heisenberg uncertainty ratio.

$r \times p \geq \hbar$ Or in a more familiar form

$$\Delta r \Delta p \geq \hbar \quad (5)$$

We obtained the known uncertainty ratio, but only did it in a simpler way (by introducing postulate 1).

b) **Postulate 2:** there is a minimum value of energy. Let's denote E_{min} - the minimum energy value. If \hbar is a constant value, then there is a minimum value ω_{min}

$$E \geq \hbar \omega_{min} \quad E/\omega_{min} \geq \hbar$$

Or in a more familiar form

$$\Delta E \Delta t \geq \hbar \quad (6)$$

The last expression can be obtained without the second postulate.

If $p = E/c$, then we can divide and multiply the lefthand side of expression (5) by c and obtain the expression (6).

c) **Postulate 3:** there is a minimum value of momentum.

$$p \geq p_{min}$$

$$\text{If } p = E/c, \text{ then } p \geq E_{min}/c$$

$$p \geq \hbar \omega_{min}/c$$

$$p/\omega_{min} \geq \hbar/c$$

$$\Delta p \Delta t \geq \hbar/c \quad (7)$$

The last expression can be obtained without the third postulate. We can divide expression (6) by c (or divide expression (5) by c) and obtain the expression (7).

Note that it's not necessary to formulate all three postulates to obtain expressions (5) - (7). It's enough to formulate any of the three postulates and hence all three expressions (5) - (7) are obtained.

Interactions Comparison

The relation of the electric interaction force to the gravitational interaction force is calculated trivially in a school physics course.

$$\frac{F_{el}}{F_{gr}} = \frac{e^2}{m^2 4 \pi \epsilon_0 G} = 4.17 \times 10^{42}$$

(8)

where e and m are the electric charge and mass of electron; ϵ_0 and G are electric and gravitational constants. A value of the same order is also given in [11].

It should be noted that so far, we can speak about the relation only of electric and gravitational forces, but not about the relation of electromagnetic and gravifrequency forces. Although in the future it will turn out that this relation is true for electromagnetic and gravi frequency interaction as well.

Let's try to calculate the relation of magnetic forces to frequency forces. The interaction force between two magnets placed in parallel is calculated by the formula [13].

$$F_{mag\ par} = \frac{0.75 \mu_0 p_1 p_2}{\pi r^4} \quad (8a)$$

where p_1 and p_2 are magnetic moments; r is the distance between the magnets. Let's calculate this force of interaction between two elementary magnets. As elementary magnets, let's take two electrons rotating along different circuits (S_1 and S_2) and with different rotation periods (T_1 and T_2)

$$F_{mag\ par} = \frac{0.75 \mu_0 \frac{e}{T_1} S_1 \frac{e}{T_2} S_2}{\pi r^4}$$

For the electron, as a mass carrier, we can write by analogy the formula for the frequency interaction force

$$F_{\omega\ par} = \frac{0.75 \mu_{0g} p_{\omega 1} p_{\omega 2}}{\pi r^4}$$

$$F_{\omega\ par} = \frac{0.75 \mu_{0g} \frac{m}{T_1} S_1 \frac{m}{T_2} S_2}{\pi r^4}$$

$$\frac{F_{mag\ par}}{F_{\omega\ par}} = \frac{\mu_0 e^2}{\mu_{0g} m^2}$$

$$\mu_{0g} = 4\pi G/c^2 \text{ (Lunin, 2024).}$$

$$\text{Then } \frac{F_{mag\ par}}{F_{\omega\ par}} = \frac{\mu_0 e^2 c^2}{4\pi G m^2}$$

$$\frac{F_{mag\ par}}{F_{gr}} = \frac{e^2}{m^2 4\pi \epsilon_0 G} = 4.17 \times 10^{42} \quad (9)$$

We obtained an expression (9) that coincides completely with expression (8).

And only now we can assert that expression (8) characterises the relation of electromagnetic interaction to gravifrequency interaction.

In [12], an analog of the Schwarzschild radius was found for the proton/electron/positron

$$r_i = \frac{e}{4\pi \epsilon_0 \lambda} \approx 10^{-15} \text{ m}$$

We can say that the protons in the nucleus are in black hole conditions, that is, every atomic nucleus is a black hole. And for each atomic nucleus there will be a different value of the Schwarzschild radius analog, depending on the nucleus charge.

And although the nucleus is limited by the Schwarzschild radius, science has been able to 'break off' pieces of the nucleus. Drawing an analogy with black holes in the Universe, we can expect that it will be possible to 'tear off' pieces from black holes in the Universe. But for this purpose, it will be necessary more 'sharp and powerful knife'. The study of black holes in the

Universe can help in the study of atomic nuclei and vice versa, and in quite different aspects.

Modern science denies the long-lived charged black holes existence possibility, believing that charges of the same sign will quickly scatter in different directions. However, it has to remember that under the black hole conditions, the Coulomb's repulsion forces become vanishingly small (a complete analogy with protons in a nucleus). Therefore, the charge in a black hole can persist for an arbitrarily long time.

Reynolds Number in Electrodynamics

Reynolds number R is calculated by the formula [14].

$$R = \frac{\rho v D}{\eta}$$

Let's replace the dynamic viscosity η by the magnetic field strength H [7].

$$\text{Then } \check{R} = \frac{\rho_e v D}{H}$$

The current I in a conductor with cross-section s can be calculated by the formula [10],

$$I = \rho_e v \times s,$$

where ρ_e = electric charge density;
 $s = \pi D^2/4$ (for a circular conductor).

Consequently $\rho_e v = I/s$

Then there is the final expression

$$\check{R} = \rho_e v D/H = I D/(s H) = 4I/(\pi D H).$$

Having obtained this formula, we can proceed to the experimental part.

Changing the magnetic field strength H , we will receive corresponding values of current I . And then we can calculate the Reynolds number in electrodynamics.

The solenoid was made of the ferromagnetic wire with a length of $l = 1.1$ m and a diameter of $D = 0.2$ mm. The wire was wound on a plastic tube with a diameter $D = 50$ mm.

The Reynolds number \check{R} values change from 1.27×10^{-3} to 2.54×10^{-3} when the current I changes from 80 mA to 160 mA with the external magnetic field strength $H = 400$ A/m.

Measurements were taken at 5 mA Intervals.

The current I change was stably observed at the external magnetic field strength H change from 400 A/m to 10^3 A/m. The current change was spasmodic, no large and very stable: from 90.2 mA to 90.1 mA (when the external magnetic field strength H reached the value of 700 A/m). A spasmodic change in resistance occurs approximately at $\check{R} \approx 1.43 \times 10^{-3}$.

The current changes remained the same when the magnetic field direction changed to the opposite.

The same change in current I (by 0.1 mA) is observed at such currents: 80 mA, 100 mA, 130 mA, 150 mA.

The magnetic field strength H change didn't lead to a current change at such currents: 60 mA, 50 mA or less. Perhaps this is

due to the insufficient accuracy of the measuring equipment. The magnetic field strength H change also didn't lead to a current I change at such currents: from 200 mA to 500 mA.

The magnetic field strength H change did not lead to a current I change in experiments with a copper wire with the diameter $D = 0.2$ mm. The external magnetic field strength H changed so: from 400 A/m up to 1000 A/m.

The experiment was carried out in the current range (20÷500) mA.

Conclusions

It's desirable to carry out further experiments in this direction with more stable and powerful power sources, with more accurate measuring equipment, with different wire diameters and knowing the magnetic permeability μ of the wire.

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Data Availability Statement

The data that supports the findings of this study are available within the article [and its supplementary material].

Conflicts of Interests

I have no conflicts of interests to disclose.

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