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THEORETICAL JUSTIFICATION OF FARADAY'S EXPERIMENTAL LAW

Vasil Tchaban

Lviv Polytechnic National University, Ukraine

vasyl.y.chaban@lpnu.ua

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Abstract. So far, the fundamental laws of nature can only be obtained experimentally. Among them is Faraday's law of electromagnetic induction in mathema-tical representation as Maxwell's second law of the elec-tric field. Theoretically, it is impossible to obtain it on the basis of the laws of electrodynamics. Therefore, in the work, a bold attempt is made to theoretically obtain its analogue in the gravitational field, and then, on the basis of electromechanical analogies, to return to the electric field. What has been successfully done. But before that, there was a need to mathematically rehabili-tate the electromechanical analogies themselves, the reputation of which had suffered in the process of the reverse extension of the law from electricity to gravity under the name of gravito(electro)magnetism. Such immersion in the world of two disciplines – electricity and mechanics – is fundamental for a deeper understanding of physical processes, and at the same time for their quantitative detection.

Key words: Faraday's law, theoretical justifica-tion, gravito(electro)magnetism, electrogravity, finite rate of propagation of electrical and mechanical inter-action.

1. Introduction

For the attention to be concentrated on the main thing, we will work on a lossless field of electric and gravitational waves. Therefore, let us start with the more usual Maxwell's second equation, which is essentially a mathematical elaboration of Faraday's experimental law of electromagnetic induction, discovered in 1836. This law was destined to play a key role in the progress of mankind, as the one that initiated the second technical revolution – total electrification. The fundamental laws of nature, as a rule, are established only experimentally, because the human mind is still far from knowing deep secrets of the universe. That is why even great scientists are still forced, like Prometheus, to steal heads from the hearth of universal Truth. But this is almost the only abduction justified by the noblest deed of the ancient hero – to save a conscious life on the Earth.

Some physicists attribute the theoretical derivation of Faraday's law to Helmholtz [1]. But a careful analysis shows that behind his mathematical exercises there is nothing more than confirmation of the truth of the experimental law – Meyer's conservation of energy, in particular, the validity of the transformation of mechanical energy into electrical energy.

Nevertheless, we will make an attempt on the basis of the theory of electrogravity [2,3] to approach the mentioned law purely theoretically on the basis of analogies between electric and gravitational fields, but in the opposite direction to what is the case in gravito(electro)magnetism [4.5]. In gravitomagnetism, due to the difficulty of relativism, Maxwell's second law of the electric field was simply extended to the case of the gravitational field. But it was not possible to do this in its pure form due to the appearance of the coefficient "2" in the mechanical equation (we will get rid of it in theoretical part). Now let us do the opposite, come to this law from the purely theoretical acquisition of me-chanics, and then extend the obtained result, to electricity.

Such immersion in the world of two disciplines – electricity and mechanics – can be used with benefit for understanding many physical processes of this world, and at the same time for their quantitative revealing. What is important that all mathematical exercises will be performed in our usual Euclidean flat space and physical time, which is also essential in terms of compliance with the basic condition of the modern theory of inflation [6]. From a cognitive point of view, this research is a continuation of a number of theoretical works published on the pages of this journal, at least in the recent ones [7,8].

The goal of the work. To prove on a strict mathematical basis an attempt to obtain Maxwell's second law, based on the theoretical acquisitions not of electricity, but mechanics. Then proceed to the result on the basis of the proven electromechanical analogies.

2. Equation of mechanical state.

As a starting point, we will take the well-known equation of the relationship between speed and acceleration in the theory of gravitational field

$$\mathbf{\Gamma} = \frac{\partial \mathbf{V}}{\partial t}, \tag{1}$$

where $\mathbf{V}, \mathbf{\Gamma}$ are linear velocity and acceleration vectors; t is time.

If we take the vector operation $\nabla\times$ from the left and right parts of (1), we get

$$\nabla\times\mathbf{\Gamma}=\frac{\partial}{\partial t}\nabla\times\mathbf{V}\,. \qquad (2)$$

The angular velocity vector $\mathbf{\Omega}$ is by definition the vortex component of the linear velocity vector

$$\nabla\times\mathbf{V}=2\mathbf{\Omega}\,. \qquad (3)$$

In order to understand the physical connection of vectors (3) and not to describe it by all projections, let us focus on the classical case of cylindrical symmetry: $\mathbf{V}=\boldsymbol{\alpha}_0 v$; $\mathbf{\Omega}'=\mathbf{z}_0\omega$, where $\boldsymbol{\alpha}_0$, $\mathbf{z}_0$ are orthogonals. Then (3) is greatly simplified

$$\frac{v}{r}+\frac{\partial v}{\partial r}=2\omega\,. \qquad (4)$$

Its obvious solution presents the well-known expressions of linear velocity and acceleration in rotational motion

$$2\frac{\partial\mathbf{\Omega}}{\partial t}=-\nabla\times\mathbf{\Gamma}\,. \qquad (5)$$

If we substitute (3) in (2), we will have

$$2\frac{\partial\mathbf{\Omega}}{\partial t}=-\nabla\times\mathbf{\Gamma}\,. \qquad (6)$$

The "-" sign in (6) is introduced by matching the vector orientation according to the right-hand screw rule. Or, speaking in the tradition of theoretical mechanics, we are not bound to acceleration, but to deceleration ($\mathbf{\Gamma}\to-\mathbf{\Gamma}$).

Equation (6) already too painfully reminds us by analogy: $\mathbf{B}\to\mathbf{\Omega}$; $\mathbf{E}\to\mathbf{\Gamma}$ Maxwell's second law

$$\frac{\partial\mathbf{B}}{\partial t}=-\nabla\times\mathbf{E}\,, \qquad (7)$$

where $\mathbf{E},\mathbf{B}$ are the electric and magnetic field intensity vectors.

Comparing (6) and (7), we really recognize Maxwell's second law in (6), but with an extra factor of 2. In gravitomagnetism, this difficulty was "solved" in a very simple way – by replacing $\mathbf{\Omega}'=2\mathbf{\Omega}$. As a result, a complete match of the above expressions was obtained. This made it possible to call expression (6) in the dashed notation one of the basic laws of gravitomagnetism (extended Maxwell's second law)

$$\frac{\partial\mathbf{B}}{\partial t}=-\nabla\times\mathbf{E}\,. \qquad (8)$$

It would seem that the problem is simply solved. But none of the creators of gravitomagnetism thought that the rest of the rotor operations in Maxwell's original equation (7) were put in a difficult position. But a pseudoanswer to this was soon found [5], such as "the gravitational field is described by a tensor of the second rank, in contrast to the electromagnetic field, which is described by a tensor of the first rank (vector)".

Below we will explain what is actually happening here.

Equation (6) was obtained on the basis of well-known truths from the student course of theoretical mechanics in the complete absence of the mentioned forces of gravitomagnetism. However, equation (7) is obtained precisely in the presence of electric magnetism! And this completely changes the matter. To understand this complex problem, electromechanical analogies obtained on the basis of the laws of statics – Newton's and Coulomb's laws are not enough for us

$$\mathbf{F}_{12}=G\frac{m_1m_2}{r^2}\mathbf{r}_{12}\,; \qquad (9)$$

$$\mathbf{F}_{12}=k\frac{q_1q_2}{r^2}\mathbf{r}_{12}\,, \qquad (10)$$

where $\mathbf{F}_{12}$ is the force vector; q, m are the interacting electric (q) (charges) or mechanical (m) masses; r is the instantaneous distance between the centers of mass; $\mathbf{r}_{12}$ is the unit vector directed from the first mass to the second; G, k are the global constants:

$$G=6{,}67438\cdot10^{-11}\,\mathrm{m^3kg^{-1}s^{-2}},$$
$$k=8.98774\cdot10^{9}\,\mathrm{N\,m^2\,C^{-2}}.$$

In the case of dynamics, you can do the same, but the force interaction equation (1) must be generalized to the case of the motion of the involved bodies [3, 7-10]

$$\mathbf{F}_{12}=G\frac{m_1m_2}{r^2}\left(1+\frac{v^2}{c^2}+2\frac{v}{c}\mathbf{v}_0\cdot\mathbf{r}_0\right)\mathbf{r}_0\,; \qquad (11)$$

$$\mathbf{F}_{12}=k\frac{q_1q_2}{r^2}\left(1+\frac{v^2}{c^2}+2\frac{v}{c}\mathbf{v}_0\cdot\mathbf{r}_0\right)\mathbf{r}_0\,, \qquad (12)$$

where v is the mutual instantaneous mass movement speed; c is the speed of light in a vacuum; $\mathbf{v}_0$ is a unit velocity vector.

The module of the force vector (11), (12) can be written component-wise:

$$F_N=G\frac{m_1m_2}{r^2}\,; \qquad (13)$$

$$F_C=k\frac{q_1q_2}{r^2}\,; \qquad (14)$$

$$F_{LN} = G\frac{m_1 m_2}{r^2}\frac{v^2}{c^2}; \quad (15)$$

$$F_L = k\frac{q_1 q_2}{r^2}\frac{v^2}{c^2}; \quad (16)$$

$$F_{TN} = 2G\frac{m_1 m_2}{r^2}\left(\frac{v}{c}\mathbf{r}_0 \cdot \mathbf{v}_0\right); \quad (17)$$

$$F_{TC} = 2k\frac{q_1 q_2}{r^2}\left(\frac{v}{c}\mathbf{r}_0 \cdot \mathbf{v}_0\right), \quad (18)$$

where F_N, F_C are Newton's and Coulomb's static forces; F_{LN}, F_L are the velocity tangential components of gravitomagnetic and Lorentz forces; F_{TN}, F_{TC} are the velocity radial components of the force of gravitational and electric interaction. It is clear that at $v \to 0$, the force interaction modulus (15−18) degenerates into (13−14), respectively.

The maximum share in the force interaction of components in pairs (15) and (16), (17) and (18) based on speed and orientation characteristics is obvious

$$\mathbf{F}_{LN} = (0 \div 1)\mathbf{F}_N; \quad \mathbf{F}_L = (0 \div 1)\mathbf{F}_C; \quad (19)$$

$$\mathbf{F}_{TN} = ((-2) \div (+2))\mathbf{F}_N; \quad \mathbf{F}_T = ((-2) \div (+2))\mathbf{F}_C \quad (20)$$

The functional dependence of forces (17) and (18) on the speed of movement is higher than that of forces (15) and (16), because under the condition $v \le c$ the multiplier v / c in (15) and (16) is raised to the second power, and in (17) and (18) – up to the first and then double! It is the components of forces (17) and (18) that close the hitherto unknown triune essence of the forces of electrical and gravitational interaction, and it is they that make it possible to solve the given problem on a strict mathematical basis.

Further, as mentioned above, we narrow the problem to electric and gravitational waves. Since electric and gravitational waves are transverse, the total gravitational and electric forces (11) and (12) are simplified, since the scalar product in this case is in advance $\mathbf{v}_0 \cdot \mathbf{r}_0 = 0$:

$$\mathbf{F}_{12} = G\frac{m_1 m_2}{r^2}\left(1 + \frac{v^2}{c^2}\right)\mathbf{r}_0; \quad (21)$$

$$\mathbf{F}_{12} = k\frac{q_1 q_2}{r^2}\left(1 + \frac{v^2}{c^2}\right)\mathbf{r}_0. \quad (22)$$

Thus, in the case of gravitational interaction, expression (21) represents the total action of gravita-tional Newtonian and gravitomagnetic forces, and in the case of electrical interaction, expression (22) represents the total action of Coulomb and Lorentz forces.

If we are talking about the Lorentz force, then its expressions repeat the discrepancy that exists between the expressions of the basic equations (6) and (7).

In the electric field, according to equation (7), we have

$$\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B}). \quad (23)$$

In the gravitational field, according to equation (6), we have something similar, taking into account electromechanical analogies

$$\mathbf{F} = m(\mathbf{\Gamma} + \mathbf{v} \times 2\mathbf{\Omega}). \quad (24)$$

Let us start from two experimental facts: electric and gravitational waves are transverse ($\mathbf{E} \perp \mathbf{B}$; $\mathbf{V} \perp \mathbf{\Omega}$) and propagate at the speed of light in vacuum c (299792458 ms-1). These conditions $v = c$ are quite sufficient to obtain, on the basis of (21), (22), expres-sions that are very important for the theory of both fields

$$\mathbf{E}_c = E\left(1 + \frac{c^2}{c^2}\right)\mathbf{r}_0 = 2\mathbf{E}. \quad (25)$$

$$\mathbf{\Gamma}_c = \Gamma\left(1 + \frac{c^2}{c^2}\right)\mathbf{r}_0 = 2\mathbf{\Gamma}. \quad (26)$$

If now in (6) and (24) we exchange the vectors $\mathbf{\Gamma} \to \mathbf{\Gamma}_c$, then everything will remain unchanged, because the factors "2" cancel themselves out. And this indicates that we operate with real physical quantities, electrical and mechanical! One can only marvel at the genius of Maxwell, who, at the dawn of the development of electrodynamics, did not fall into the same trap in which the prolongators of his gravity equations fell. And the answer to this question is quite simple – magnetism was involved in Maxwell's equations as a speed compo-nent of motion. Therefore, the vector of the field intense corresponded in advance not to statics (10), but to dynamics (21).

Thus, we have every right to omit the stroke in the notation (8) and (24) and thereby recognize the complete correspondence of the basic equations of electricity (7) and (23) and the equations of gravity corrected from or (8) and (24) as

$$\frac{\partial \mathbf{\Omega}}{\partial t} = -\nabla \times \mathbf{\Gamma}; \quad (27)$$

$$\mathbf{F} = m(\mathbf{\Gamma} + \mathbf{v} \times \mathbf{\Omega}). \quad (28)$$

Thus, in the comparative pairwise comparison of expressions (7) and (27), (24) and (28), we once again confirmed the omnipresent unity of nature.

It was proved in [8] that the force component (16) determined by the tangential component of the speed of movement completely coincides with the Lorentz force, which in classical electrodynamics presents the force action of the magnetic field, or the so-called speed (relativistic) effect in the electric field. Being prolonged for gravitational interaction, it presents the correspon-ding gravito(electro)magnetic force [4,5].

3. Conclusions

1. The rapid successes of experimental celestial mechanics with its simultaneous theoretical stagnation created a critical need to turn for immediate help to the methods of electromagnetic field theory, in particular to its magnetic component caused by motion. As a result, the force-magnetic interaction of the electric field, based on electromechanical analogies, was extended to the gravitational field under the name of gravito(elect-ro)magnetism. However, it was not possible to do it painlessly because of the obvious – the electric field was strengthened by the force component of the movement, and the gravitational field brought it based on the equations of statics. In this work, this was taken into account, as a result of which it was possible to completely assimilate the equations of electricity and gravity, thereby giving electromechanical analogies a strictly mathematical basis.

2. As for Faraday's law of electromagnetic induction (in the representation of Maxwell's second law), it is still impossible to obtain it by the methods of theoretical electrical engineering. In this paper, a bold attempt is made to theoretically obtain its analog in the gravitational field, and then, on the basis of rehabilitated electromechanical analogies, to substantiate it in the electric one. Which has been successfully done.

4. References

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ТЕОРЕТИЧНЕ ОБҐРУНТУВАННЯ ЕКСПЕРИМЕНТАЛЬНОГО ЗАКОНУ ФАРАДЕЯ

Василь Чабан

Фундаментальні закони природи поки що вдається отримувати лише експеримент-тально. До їхнього числа належить і закон Фарадея про електромагнітну індукцію в математичному представленні як другий закон Максвелла електричного поля. Теоретично його отримати на підставі законів електродинаміки непосильно. Тож, у роботі зроблено смі-ливу спробу теоретично одержати його аналог у гра-вітаційному полі, а вже затим на підставі електромеханічних аналогій повернутися в електричне поле. Що успішно зроблено. Але до того виникла потреба математично реабілітувати самі електромеханічні аналогії, репутація яких постраждала в процесі зворотної пролонгації закону з електрики в гравітацію під назвою гравіто(електро)магнетизму. Таке заглиблення у світ двох дисциплін – електрики і механіки – корисне для поглибленого розуміння фізич-них процесів, а заодно їх кількісного виявлення.

Vasil Tchaban: D.Sc, full professor at Lviv Polytechnic National University (Ukraine), as well as Lviv Agrarian National University, Editor-in-Chief of Technical News journal. His Doctor-eng. habil degree in Electrical Engineering he obtained at Moscow Energetic University (Russia) in 1987. His research interests are in the areas of mathe-matical modeling of electromechanical processes in electric and gravity fields theories, and surrealistic short story writter. He is the author of 550 scientific publications and 800 surrealistic short stories including 52 books (14 monographs, 17 didactics, 11 humanistic, and 10 of the arts), and 1500 aphorisms. The total number of publications is over 1500.

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