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Dependence of Electrodynamics on the Models of the Electromagnetic Medium

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Abstract: This article traces the influence of physical models of the electromagnetic medium on electrodynamics. The connection between the ability of the electrodynamic equations to describe the processes under study and the adequacy of the model of the electromagnetic medium used in their derivation to the known data is shown. It is revealed that the assumption of the absence of the existence of the electromagnetic medium leads to certain methodological difficulties in deriving the electrodynamic equations. The paper highlights the main milestones in the evolution of the physical model of electromagnetic medium. As a rule, the existence of electromagnetic medium in physics has been denied up to the present time due to the lack of its consistent model. A new physical model of the electromagnetic medium is developed and based on it a system of electrodynamic equations is derived that agree with the known data of physical experiments and astronomical observations. On the basis of the proposed physical model, a mathematical description of the method of detecting the electromagnetic medium is obtained. The developed physical model made it possible not only to explain the data of known electromagnetic phenomena and experiments, but also to propose the Galilean relativity principle within the framework of classical mechanics. Possible consequences of detection of the electromagnetic medium are discussed.

Keywords: Electrodynamics, Electromagnetic Medium, Principle of Galilean Relativity

1. Introduction

The experimental laws of Ampere and Faraday allowed Maxwell to develop the theoretical foundations of electrodynamics [1, 2]. Developing his theory, Maxwell suggested the existence of the "electromagnetic medium" in which light propagates. Subsequently, models of the electromagnetic medium continued to be developed by various researchers.

In this article a connection between the ability of electrodynamic equations to describe the mutual influence of moving matter (bodies or media) with electromagnetic waves and the adequacy of the model of the electromagnetic medium used in their derivation to the known data is traced.

Minkowski derived electrodynamic equations assuming the absence of the electromagnetic medium [3]. The article shows the methodological difficulties arising in the process of deriving electrodynamic equations under this assumption.

The analysis of the processes that allow discovering the existence of the electromagnetic medium is carried out. Based on this analysis, a physical model of the electromagnetic medium and the equations of electrodynamics are developed that describe the method of detecting the electromagnetic medium.

2. Main Part

Maxwell, studying the results of Faraday's experimental studies of electromagnetic induction, derived equations describing this phenomenon for the case of stationary matter [1, 2]. These equations can be represented as

$$\nabla \times \mathrm{E} = -\frac{\partial \mathrm{B}}{\partial t} \tag{1}$$

$$\nabla \times \mathrm{H} = \mathrm{I}, \tag{2}$$

where E, H, B, and I are vectors of electric and magnetic field strengths, magnetic induction and current (including displacement current) density, respectively; t – time.

Exactly these equations are called Maxwell electrodynamic equations. Maxwell's electrodynamics uses a physical model based on the concept of the existence of the electromagnetic medium [1, 2] called Medium further in the paper. The Medium is a fine substance, fills the whole of space and matter and is a carrier of electromagnetic phenomena. Electromagnetic waves propagate in the Medium independently of the motion of the source of the waves relative to the coordinate system fixed in the Medium at the velocity of light $c=(\varepsilon_0\mu_0)^{-\frac{1}{2}}$, where ε0 and μ0 are the electric constant or vacuum permittivity and the magnetic constant or vacuum permeability, respectively. Maxwell considered the Medium stationary and equations (1)-(2) do not describe electrodynamic phenomena due to motion. These equations are not electrodynamic in the strictly sense – they can describe the work of transformer but they can't describe the work of generator.

Maxwell himself and then Hertz went on to deduce the electrodynamic equations for the moving matter conditions. Hertz used a model according to which the matter completely carry along surrounding it Medium. Using his model of the Medium, Hertz derived the equations [4]:

$$\nabla\times\mathrm{E}=-\frac{\partial\mathrm{B}}{\partial t}-\nabla\times(\mathrm{B}\times\mathbf{v}) \tag{3}$$

$$\nabla\times\mathrm{H}=\frac{\partial\mathbf{D}}{\partial t}+\mathbf{j}+\rho v+\nabla\times(D\times v), \tag{4}$$

where D is vector of electric induction; j is the conduction current density vector; v is the matter velocity vector (measured relative to the laboratory coordinate system; the source of the magnetic field is assumed to be motionless relative to the laboratory coordinate system) and ρ is the density of free-moving charges.

It is important to note that equations (1)-(4) follow from the general integral equations [5, 6]:

Faraday's induction law

$$\oint_s \mathrm{E}_s\,ds=-\frac{d}{dt}\int_\delta \mathrm{B}_n\,d\delta \tag{5}$$

Ampere's law

$$\oint_s H_s\,ds=-\int_\delta I_n\,d\delta, \tag{6}$$

where E_s and H_s are tangential components of vectors E and H to a closed loop s; B_n and I_n are normal components of vectors B and I to an arbitrary surface δ confined by the loop s.

Equations (1)-(2) follow from (5)-(6) for the stationary matter and equations (3)-(4) - for the moving matter conditions.

Hertz equations correctly describe the phenomena of induction in moving conductors, but not in moving dielectrics. In addition, according to these equations the movement of empty space could cause electromagnetic induction (the last terms in the right parts of the equations (3)-(4)).

The indicated errors of Hertz's theory are a consequence of the shortcomings of his model of the Medium which, for example, is unable to explain phenomena with partial carrying along of the Medium by moving matter.

There was no satisfactory model of the Medium when Minkowski developed electrodynamic theory. In addition, by this time all the proposed methods for discovering the existence of the Medium were not justified. As a result, Minkowski derived electrodynamic equations assuming the absence of the Medium [3]. The denial of the existence of the Medium led Minkowski to use the following principle of relativity: the laws of physics have the same form in all inertial frames of reference.

Using this principle, Minkowski received electrodynamic equations consisted of the Maxwell field equations for stationary matter and constitutive equations that take into account movement of the matter (similar equations can be obtained from the Lorentz electron theory).

So, in Minkowski equations Maxwell stationary induction equation (1) is used as an equation of electromagnetic induction for the processes in moving matter. This, in particular, means that the original integral equation (5) is replaced by the equation

$$\oint_s \mathrm{E}_s^*\,ds=-\frac{d}{dt}\int_\delta \mathrm{B}_n\,d\delta, \tag{7}$$

where E_s^* is the tangential component of electric field strength, measured in the coordinate system moving together with the matter.

In contrast to (5) equation (7) cannot be called Faraday's induction law, and it is not it either since the use of this equation means not only the loss of information about induction due to motion, but also the distortion of Faraday's experiments conditions. Faraday carried out his measurements in the experiments we examined in the laboratory coordinate system, but not in a coordinate system moving with the matter relative to the laboratory coordinate system (or, which is the same) relative to the source of the magnetic field [7]. Equation (1) lacks information of induction due to motion and the need to use an additional relation that takes into account this induction (e.g. the Lorentz force relation) arises.

As a result, in Minkowski equations the law of induction is represented by equation (1) and equation

$$\mathbf{E}^*=\mathbf{E}+\frac{1}{c}\mathbf{v}\times\mathbf{B}, \tag{8}$$

where $\mathbf{E}^*$ is the vector of electric field strength, measured in the coordinate system moving together with the matter.

Thus, the single general principle of induction is described by two different laws, expressed, respectively, by two different equations [8]. It is easy to show that when the equation (8) is substituted into the remaining equations, a new derivative of v × B arises which has no physical nature. This can have an effect not only on the accuracy of the calculations but also on the possibility of adequate investigation of a number of processes in question by means of these equations.

An alternative way to obtain electrodynamic equations is to assume the existence of the Medium and develop its physical model consistent with known data.

Such a model was developed in previous studies [9, 10]. This work is continued in this article. The essence of the model consists in the following. We assign the electric and the magnetic constants, ε_0 and μ_0, to the Medium. The Medium, having negligible mass, is subjected to gravity like any matter and has a very small viscosity. The force of Earth's gravitation acting on the Medium predominates over any other gravitation actions on the surface of Earth with the exceptions of the close vicinity of atomic structures of the matter. So, moving matter on the surface of Earth does not drag on the surrounding Medium but only in the close vicinity of its atomic structures.

The represented model includes elements of the well-known models of the Medium: Stokes' model of complete entrainment of the surrounding Medium by moving matter (Medium is carried along by Earth in its orbital movement – experiment by Michelson and Morly), Fresnel's model of partial convection of the surrounding Medium by moving matter (Medium is carried along in the close vicinity of atomic structure of the matter - experiment by Fizeau) and Lorentz' stationary Medium model (Medium is not carried along by the daily rotation of Earth as a consequence of the negligibly low viscosity - experiment by Michelson–Gale).

It is known that Stokes obtained the correct formula for stellar aberration using the model of the total entrainment of the Medium [11], but Lorentz found a contradiction in his physical basis for this formula. Due to the complete entrainment of the Medium, its velocity on the Earth's surface must have a potential, which contradicts the conditions of applicability of the mathematical apparatus used by Stokes. The model of the Medium proposed in the paper is incompatible with the potential motion of the Medium on the Earth's surface due to its non-entrainment during the daily rotation of the Earth and so the Medium rotates about the axis draw across Earth's ecliptic plain.

As a result, the contradiction noted by Lorentz is overcome. Using the Stokes mathematical apparatus [11], we obtain the well-known formula for stellar aberration for the Earth $-\frac{\mathbf{v}_0}{c}$, where v_0 is vector of the orbital velocity of the Earth revolving around the sun.

Moreover, the model of the Medium makes it possible to get by analogy the formula for stellar aberration for the moon A_m

$$A_m = -\frac{\mathbf{v}_0 + \mathbf{v}_m}{c}, \tag{9}$$

where $\mathbf{v}_m$ is vector of the orbital velocity of the moon revolving around the Earth.

This formula is easily generalized to other space objects.

According to the offered physical model, the Medium with its ε_0 and μ_0 is not carried along by moving matter. It explains why moving matter carries with itself in its motion only the polarization current and the magnetic induction (as was revealed experimentally [12, 13]. That is why the electromagnetic induction due to motion of the matter depends on how much the product of $\mu\varepsilon$, ε is the electric permittivity and μ is the magnetic permeability, in the moving matter exceeds the product $\mu_0\varepsilon_0$ in the surrounding Medium. As a result, in contrast to the Hertz equations, the factor α appeared in the last terms of the right-hand sides of equations (3)-(4) [9, 10]

$$\alpha = \frac{\mu\varepsilon - \mu_0\varepsilon_0}{\mu\varepsilon}. \tag{10}$$

Due to the factor α these equations in contrast to the Hertz ones are consistent with experimental data concerned with the movement of dielectrics and optical phenomena. Also, in contrast to the Hertz equations, thanks to the presence of the factor α, the movement of empty space can't cause electromagnetic induction ($\alpha \to 0$ with $\rho \to 0$).

The presented model gives rise to another way of discovering the existence of the Medium (in addition to measuring stellar aberration on space objects). If a closed loop is made of a dielectric, then the factor α will become, as for a conductor equal to 1 when its velocity becomes equal to the velocity of the surrounding Medium. In order to achieve this, the speed of the loop must be equal to the speed of the daily rotation of the Earth, taken with the opposite sign, at a given point on the earth's surface.

Let us include the above described method of discovering the existence of the Medium in the mathematical model. This inclusion can be done by changing the factor α in the following way:

$$\alpha = \frac{\mu\varepsilon - \mu_0\varepsilon_0\,(1 - f(\mathbf{v} - \mathbf{v_M}))}{\mu\varepsilon}, \tag{11}$$

where v, as before, is the matter velocity vector and $\mathbf{v_M}$ is the velocity of the surrounding Medium.

The function f has the following properties: f (u) = 1 for u = 0, and f (u) = 0 for u ≠ 0, u € R. Some properties of this function are described in previous studies [14]. It is natural to assume that in reality the function f should not be discontinuous at the point u=0 but has some transition interval that can be determined further in the corresponding experimental studies.

Equation (11) describes the above-mentioned process, which, if implemented, will be a proof of the existence of the Medium: under the condition v = $\mathbf{v_M}$ the factor α becomes equal to 1 for dielectrics.

As a result, the system of electrodynamic equations takes the following form based on previous research [9, 10]:

$$\nabla\times\mathrm{E} = -\frac{\partial \mathrm{B}}{\partial t} - \nabla\times(\alpha\mathrm{B}\times\mathbf{v}) \tag{12}$$

$$\nabla\times \mathrm{H}=\frac{\partial \mathbf{D}}{\partial t}+\mathbf{j}+\rho v+\nabla\times(\alpha D\times v) \tag{13}$$

$$\nabla\cdot D=\rho$$

$$\nabla\cdot B=0 \tag{14}$$

$$D=\varepsilon E;\quad B=\mu H;\quad j=\sigma E \tag{15}$$

$$\alpha=\frac{\mu\varepsilon-\mu_0\varepsilon_0\,(1-f(\mathbf{v}-\mathbf{v_M}))}{\mu\varepsilon}, \tag{16}$$

where σ is the conductivity of a medium.

In the case of stationary matter equations (12)-(16) will transform to the Maxwell equations (1-2). In the case of conductors ($\alpha=1$), equations (12)-(16) turn into Hertz's equations (3-4).

By introducing vector potential A, $B=\nabla\times\mathrm{A}$ and scalar potential φ, we find from (12)

$$\mathrm{E}=-\frac{\partial \mathrm{A}}{\partial t}-\nabla\phi-\alpha\mathrm{B}\times\mathbf{v}\,. \tag{17}$$

Let's analyze the strength of electric field induced by the movement of the loop in the magnetic field, E_m :

$$\mathrm{E}_m=-\alpha\mathrm{B}\times\mathbf{v}\,. \tag{18}$$

It is completely consistent with the experimental data of Faraday, who used conductors [7], and with the experimental data of the Wilsons, who used dielectrics [15].

Let's analyze the strength of magnetic field induced by the movement of the loop in the electric field, H_m . We find from (13)

$$\mathrm{H}_m=-\alpha\mathbf{D}\times\mathbf{v}\,. \tag{19}$$

It complies with the experimental data of Rowland and Eichenwald, who used conductors [12, 13], and with the experimental data of Roentgen and Eichenwald, who used dielectrics [12, 13]. The system (12-16) is adequate to the mutual influence of moving matter (bodies or media) with electromagnetic waves and therefore is effective for use in applied research [16].

3. Discussion

1) Let us analyze the generalization of the Galilean relativity principle of mechanical processes to electrodynamics.

Galileo pointed on the identity of laws of mechanics on the shore (on the surface of Earth) and on a moving large ship in an indoor cabin below deck (which carries the contained air in its movement) but not in a deck in the open air (which does not carry along the ambient air in its movement) [17]. Let us call inertial systems that carry along with themselves in their uniform motion the environment participating in the investigated processes as Galileo's systems. Generalizing Galileo's condition of the applicability of the relativity principle to electrodynamic phenomena in accordance with the represented physical model, one has demand that Galileo's systems should be carried along in their uniform motion surrounding them Medium and be far enough from all external masses because the Medium is subjected to gravitation. In these isolated systems, light is propagated with velocity c, electrodynamic equations are the same and can be considered as Galilean-invariant.

2) The use of the model of the Medium in the development of electrodynamics gives the process a fundamental classical basis and frees it from the need to accept additional postulates.
3) If the existence of the Medium is proved (the corresponding methods are presented above) then, in accordance with the indicated characteristics (fills the whole of space, has a certain mass and is exposed to gravity like any matter), it can be assumed that it is its mass provides the observed rotation of galaxies and therefore the concept of dark matter can be attributed to the Medium.

4. Conclusion

The expediency of using the physical model of the Medium in the development of electrodynamics is substantiated. The connection between the ability of the electrodynamic equations to describe the processes under study and the adequacy of the model of the electromagnetic medium used in their derivation to the known data is shown.

Presented physical model of the Medium and the electrodynamic equations derived from it agree with the known data. On the basis of the proposed physical model, a mathematical description of the method of detecting the Medium is obtained.

The developed physical model made it possible not only to explain the data of known electromagnetic phenomena and experiments, but also to propose the Galilean relativity principle within the framework of classical mechanics.

If its existence is confirmed the properties of the Medium will make it a possible candidate for participation in the structure of the so-called dark matter.

References

[1] J. C. Maxwell, A Treatise on Electricity and Magnetism (Clarendon, Oxford, Vol. 1, ed. 3, 1891) - (reprinted Dover, New York, 1954).

[2] J. C. Maxwell, Phil. Trans. R. Soc. Lond. 155, 459 (1865).

[3] H. Minkowski, Nachr. K. Ges. Wiss. Gottingen, 53 (1908).

[4] H. Hertz, Wied. Ann. 41, 369 (1890).

[5] M. Planck, Theory of Electricity and Magnetism, Macmillan and co., London 1932.

[6] A. Sommerfeld, Electrodynamik, Akademische Verlagsgesellchaft, Leipzig 1949.

[7] M. Faraday, Experimental Researches in Electricity: Great Books of the Western World, Vol. 42. Encyclopedia Britannica, University of Chicago 1994.

[8] R. Feynmann, R. Leighton, and M. Sands, The Feynmann's Lectures on Physics, California Institute of Technology: Addison-Wesley, Massachusetts, Palo Alto, London 1964.

[9] A. Rozov, Z. Naturforsch. 72, 757 (2017). 10.1515/zna-2015-0142.

[10] A. Rozov, Z. Naturforsch. 70, 1019 (2015).10.1515/zna-2016-0287.

[11] H. A. Lorentz, The Theory of Electrons, Dover, New York 1952.

[12] M. Born, Einstein's Theory of Relativity, Dover Publications, New York 1962.

[13] W. Pauli, Theory of Relativity. Pergamon Press, London 1958.

[14] B. R. Gelbaum and Y. M. H. Olmsted, Counterexamples in analysis, Holden-Day, San Fracisco, Amsterdam 1964.

[15] M. Wilson and H. A. Wilson, Phil. Trans. Roy. Soc. A 89, 99 (1913).

[16] A. Rozov, Mathematical Models and Computer Simulations, 12, 613 (2020). 10.1134/S207004822004016X.

[17] J. Seeger, Galileo Galilei, His Life and His Works, Pergamon Press, Oxford 1966.