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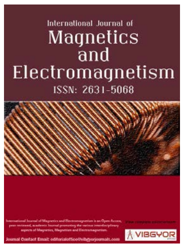

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Dependence of Electrodynamics on the Model of the Electromagnetic Medium

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Abstract

The 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 models 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 consistency of the proposed model of the Medium and the electrodynamic equation with experimental data and astronomical observations is shown, as well as the possibility of their improvement.

A method for describing the influence of the electromagnetic medium on the process of electromagnetic induction by the electrodynamic equations is proposed.

The characteristics of the electromagnetic medium following from the proposed physical model make the electromagnetic medium, if its existence is discovered (corresponding detection methods are given), a candidate for the role of so-called dark matter.

Keywords

Electrodynamics, Electromagnetic medium, Principle of relativity, Dark matter

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 processes of interaction between electromagnetic fields and matter (body or medium - for example, plasma) and the adequacy of the models 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 electrody-

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namic 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, the equations of electrodynamics obtained in [4,5] are improved by the ability to describe the effect of the electromagnetic environment on the process of electromagnetic induction.

Reasons are given to consider the electromagnetic medium, if its existence is discovered, as a candidate for the role of so-called dark matter.

Main Part

Initially Maxwell derived electrodynamic equations for the stationary matter [1,2].

We write these equations in the following form:

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

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

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 ε_0 and μ_0 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.

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. As a result, he obtained the following equations [6]:

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

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

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 [7,8].

-- Faraday's induction law

$$\oint_s E_s ds=-\frac{d}{dt}\int_\delta B_n d\delta, \tag{5}$$

-- Ampere's law

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

Where $\mathbf{E}_s$ and $\mathbf{H}_s$ are tangential components of vectors **E** and **H** to a closed loop s; $\mathbf{B}_n$ and $\mathbf{I}_n$ 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 they were not in agreement with experimental data concerned with the movement of dielectrics and optical phenomena. 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.

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 Hertz 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

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

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 [9]. 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

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

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

Thus, the single general principle of induction is described by two different laws, expressed, respectively, by two different equations [10]. 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 plasma instability in the phenomena 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 started to be developed in [4,5]. This work is continued in this article. Despite the fact that the development of the model is, in fact, at an early stage, its current level allows not only to derive electrodynamic equations, but also to provide physical explanations for a number of important processes.

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 matter. So, moving matter on the surface of Earth does not drag on the surrounding Medium.

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 (is carried along by Earth in its orbital movement), Fresnel's model of partial convection of the surrounding Medium by moving matter (is carried along exclusively in the close vicinity to its atomic structure) and Lorentz' stationary Medium model (is not carried along by moving matter on the surface of Earth and the daily rotation of Earth as a consequence of the negligibly low viscosity).

In the future, it is necessary to include in the model elements of the internal structure of the Medium.

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 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, we obtain the well-known formula for stellar aberration for the Earth $-\frac{\mathbf{v}_0}{c}$,

Where, $\mathbf{v}_0$ 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

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

Where, $\mathbf{v}_m$ is vector of the orbital velocity of the moon revolving around the Earth, respectively. This formula is easily generalized to other space objects.

In [4,5] was presented the system of electrodynamic equations derived using the proposed model of the Medium.

This system of equations was different from the Hertz equations by the presence of factor α in the field equations

$$\alpha = \frac{\mu\varepsilon - \mu_0\varepsilon_0}{\mu\varepsilon}, \quad (10)$$

Where ε is the electric permittivity and μ is the magnetic permeability of a matter.

Due to 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.

According to the offered physical model, the Medium with its ε_0 and μ_0 is not carried along by moving medium. 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 $\mu\varepsilon$ 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 factors α appeared in the last terms of the right-hand sides of equations (3-4) [4,5].

The 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:

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

Where **v**, as before, is the matter velocity vector and $\mathbf{v}_\mathbf{M}$ is the velocity of the Medium.

Function f (u) = 1 for u = 0, and f (u) = 0 for u ≠ 0, u € R. Some properties of this function are described in [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.

As a result, the system of electrodynamic equations takes the form

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

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

$$\nabla \cdot D = \rho; \quad \nabla \cdot B = 0, \quad (14)$$

$$D = \varepsilon E; \quad B = \mu H; \quad j = \sigma E, \quad (15)$$

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

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)

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

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

$$\mathrm{E}_m = -\alpha \mathrm{B} \times \mathbf{v}. \quad (18)$$

Equation (18) describes the effects of induction of an electric current when moving in a magnetic field a conductor - the Faraday experiment, ($\alpha \to 1$) [9] - and a magnetized dielectric - the Wilsons' experiment [15]. The case of a dielectric moving in an electric field was first investigated by Roentgen [13]. Accurate quantitative data were obtained by Eichenwald [13]. The result obtained - the measured value of the magnetic field - fully corresponds to the relationship following from the equation (13): Magnetic field strength induced by the movement of the loop in the electric field, H_m:

$$\mathrm{H}_m = -\alpha \mathbf{D} \times \mathbf{v}. \quad (19)$$

The resulting system of equations and its solutions for various special cases are convenient for use in applied research [16].

The proposed model of the Medium needs its further development. Nevertheless, its present level allows not only to obtain adequate electrodynamic equations, but also to formulate the principle of relativity by summarizing known data and generalizing Galileo's condition of the applicability of the relativity principle of mechanical processes for inertial systems [17] to electrodynamic phenomena in accordance with the model as follows: The laws of electrodynamics are the same in inertial systems of reference carrying along in their uniform motion surrounding them Medium. In these systems light is propagated with the velocity c relative to their local Medium and electrodynamic equations are the same and can be considered as Galilean-invariant. Following [18], we will believe that these frames of reference have a sufficiently large mass and are sufficiently distant from other systems to carry along in their uniform motion surrounding them environment, including, for example, the Medium and, if it exists, an ambient air. One can assume that in reality the principle of relativity is fulfilled in isolated space objects, as it was first noted in [13].

Discussion

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 that do not always have a convincing evidence base.

If the existence of the Medium is discovered (the corresponding methods are presented above) then, in accordance with the indicated characteristics (fills the whole of space and matter, has a certain mass and is exposed to gravity like any matter), it is probably what we call dark matter.

Summary

The expediency of using the physical model of the Medium in the development of electrodynamics is shown. The connection between the ability of the electrodynamic equations to describe the processes under study and the adequacy of the models of the electromagnetic medium used in their derivation to the known data is shown. The consistency of the proposed model of the Medium and the electrodynamic equation with experimental data and astronomical observations is shown, as well as the possibility of their improvement.

A method is developed for describing the influence of the Medium on the process of electromagnetic induction by the electrodynamic equations.

There are reasons to consider the Medium if its existence is confirmed (methods for discovering the existence of the Medium are proposed) as a candidate for the role of so-called dark matter.

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