Maxwell equations are necessary?

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Abstract

The important task of electrodynamics is the presence of laws governing the appearance of electrical pour on, and, therefore, also the forces of those acting on the charge, at the particular point spaces, since only electric fields, generated other one or method or another, exert power influences on the charge.

The important task of electrodynamics is the presence of laws governing the appearance of electrical pour on, and, therefore, also the forces of those acting on the charge, at the particular point spaces, since only electric fields, generated other one or method or another, exert power influences on the charge. Such fields can be obtained, changing the arrangement of other charges around this point of space or accelerating these charges. If around the point in question is some static configuration of charges, then the tension of electric field will be at the particular point determined by the relationship of $\vec{E} = -grad\ \varphi$, where φ the scalar potential at the assigned point, determined by the assigned configuration of charges. If we change the arrangement of charges, then this new configuration will correspond other values of scalar potential, and, therefore, also other values of the tension of electric field. But, making this, it is necessary to move charges in the space, and this displacement in the required order is combined with their acceleration and subsequent retarding. Acceleration or retarding of charges also can lead to the appearance in the surrounding space of induction electrical pour on. in the electrodynamics the fundamental law of induction is Farrday law. It is written as follows:

$$\text{of } \oint \vec{E}\, d\vec{l} = -\frac{\partial \Phi_B}{\partial t} = -\mu \int \frac{\partial \vec{H}}{\partial t}\, d\vec{s} = -\int \frac{\partial \vec{B}}{\partial t}\, d\vec{s}, \qquad (1.2)$$

where $\vec{B} = \mu \vec{H}$ - magnetic induction vector, $\Phi_B = \mu \int \vec{H}\, d\vec{s}$ - flow of magnetic induction, and $\mu = \tilde{\mu}\mu_0$ - magnetic permeability of medium. It follows from this law that the circulation integral of the vector of electric field is equal to a change in the flow of magnetic induction through the area, which this outline covers. It is immediately necessary to emphasize the circumstance that the law in question presents the processes of mutual induction, since for obtaining the circulation integral of the vector $\vec{E}$ we take the strange magnetic field, formed by strange source. From relationship (2.1) obtain the first Maxwell equation

$$rot\ \vec{E} = -\frac{\partial \vec{B}}{\partial t}. \tag{2.2}$$

Let us immediately point out to the terminological error. Farrday law should be called not the law of electromagnetic, as is customary in the existing literature, but by the law of magnetoelectric induction, since. a change in the magnetic pour on it leads to the appearance of electrical pour on, but not vice versa.

In connection with the data by examination let us give the exception to the rule of flow, to which, until now, no one turned attention. Occurs possible such case, when the flow through the cross section of outline not at all changes, and current in the outline, and, therefore, also EMF, its exciting, it occurs. Let us place in the long solenoid the superconducting cylinder somewhat smaller diameter. If we now begin to introduce current into the solenoid, then persistent current will begin to be directed on the external surface of the superconductive cylinder, in this case, however, magnetic flux inside the superconductive cylinder will be always equal to zero.

In order to leave the difficulties examined, let us make the attempt to approach the law of magnetoelectric induction from several other side. Let us assume that in the region of the arrangement of the outline of integration there is a certain local vector $\vec{A}_H$, which satisfies the equality

$$\mu \oint \vec{A}_H\, d\vec{l} = \Phi_B ,$$

where the outline of the integration coincides with the outline of integration in relationship (2.1), and the vector of is determined in all sections of this outline, then

$$\vec{E} = -\mu \frac{\partial \vec{A}_H}{\partial t}. \tag{2.3}$$

Introduced thus vector of determines the local connection between it and by electric field, and also between the gradients this vector and the magnetic field. If it will be possible to determine the vector $\vec{A}_H$, its time derivative at any point of space, and also its gradients, then will succeed in determining the vector $\vec{E}$, and the vector $\vec{H}$. It is not difficult to show that introduced thus vector $\vec{A}_H$, is connected with the magnetic field with the following relationship:

$$rot\ \vec{A}_H = \vec{H}\ . \tag{2.4}$$

At those points of the space, where

$$rot\ \vec{A}_H = 0,$$

magnetic field is absent, however, on the basis of reasonings about the vector potential around the long solenoid, this does not mean that at these points there is no vector $\vec{A}_H$ and that at these points of space, as can be seen from relationships (2.3), cannot be generated electric field.

Thus, we will consider that the vector $\vec{H}$ exists by a consequence of the presence of the vector $\vec{A}_H$, but not vice versa. For example, outside the long solenoid of $rot\ \vec{A}_H = 0$ and magnetic fields be absent, but there is a vector $\vec{A}_H$, and electric fields are generated with its change with time. In the case of the superconductive cylinder, placed inside the solenoid, the currents on its surface also can be generated, if vector potential changes on this surface. With this approach for us to be necessary to accept the assertion, that around the long solenoid there is a circulation of vector potential, and precisely it is critical for the appearance of circulation of electric field with a change of the electric flux in the solenoid. But, if this concept will be accepted, then should be changed the interpretation apropos of the reasons for the appearance of electric field, after concluding that the electric field is generated, where it does not change magnetic field, but, where changes vector potential.

If there is a straight conductor with the current, then around it also there is a field of vector potential, the truth in this case $rot\ \vec{A}_H \neq 0$ in the environments of this conductor is, therefore, located also the magnetic field, which changes with a change of the current in the conductor. The section of wire by the length dl, over which flows the current I, generates in the distant zone (it is thought that the distance r considerably more than the length of section) the vector potential

$$d\vec{A}_H(r) = \frac{Id\vec{l}}{4\pi r}.$$

Let us note the circumstance that the vector potential in this case diminishes as $\frac{1}{r}$, and according to the same law, in accordance with relationship (2.3), diminish the induced electric fields. Thus, at large distances the law of induction continues to work; however, the induced electric fields already completely depend only on vector potential and, which is very important, they diminish no longer as $\frac{1}{r^2}$, as in the case of scalar potential, but as $\frac{1}{r}$, which is characteristic for the radiating systems.

It would seem, everything very well is obtained, but here we again encounter, first hp by the incorrect treatment of the concept of vector potential, then hp by the incorrect treatment of its appearance. With the presence of electrical pour on the specific energy, connected with their existence, it is found from the relationship of

$$W_E = \frac{1}{2}\varepsilon E^2,$$

where $\varepsilon = \tilde{\varepsilon}\varepsilon_0$ - dielectric constant of medium.

However, with this interpretation of the appearance of vector potential around the long solenoid, it turns out that electric fields around the long solenoid, in which changes the current, can exist, but energy in these fields is not stocked. Until to the solenoid is connected the power source, around the solenoid of electrical pour on no. But at the moment of the connection to it of dc power supply current in its winding begins to grow according to the linear law, and around the solenoid in accordance with the concept of vector potential accepted instantly appears the circulation of electric field. Moreover, since the current in the solenoid grows according to the linear law, these electric fields are time-constant. Electric fields also instantly disappear, when a change in the current ceases. That that the fields can instantly appear and disappear already it directs at the reflection, moreover, in these fields is not stocked energy. The fact that this so, testifies the fact that with the calculation of the energy, stored up in the solenoid, it is considered only magnetic fields inside the solenoid itself. Current in the solenoid they be absent at the moment of the connection of the voltage source, and, which means, is absent the energy stored in it, but the circulation of electric field around the solenoid has already been located. And here here again is a almost absurd situation, when electric fields exist, but energy in them is not stocked. But once of field appear instantly and do not contain energy, then they possible to assume that and are extended with the infinite velocity. Furthermore, if solenoid is very long (in the literature sometimes even it is used expression infinitely long solenoid), then, as to explain and the fact that at all points of space inside this solenoid magnetic field grows according to the identical law. This also means that the magnetic field inside the solenoid has lengthwise infinite phase speed, and thus we can transfer information with the infinite velocity. The facts examined, to which thus far attention did not turn, are, perhaps, the most important obstacle on the way of this interpretation of the appearance of vector potential around the long solenoid, although precisely this concept of its appearance is examined in all works on electrodynamics. But let us thus far leave this most important question in the shadow, since, if we this do not make, then one should forego a whole series of ideas and concepts, which occur in the classical electrodynamics. Below this question will be in detail examined, and it will be given let us elucidate, with which such contradictions are connected.

Until now, resolution of a question about the appearance of electrical pour on in different inertial moving systems (IMS) it was possible to achieve in two ways. The first - consisted in the calculation of the Lorentz force, which acts on the moving charges, the alternate path consisted in the measurement of a change in the magnetic flux through the outline being investigated. Both methods gave identical result. This was incomprehensible. In connection with the incomprehension of physical nature of this state of affairs they began to consider that the unipolar generator is an exception to the rule of flow [1]. Let us examine this situation in more detail.

In order to answer the presented question, should be somewhat changed relationship (2.9), after replacing in it partial derivative by the complete:

$$\vec{E}' = -\mu \frac{d\vec{A}_H}{dt}. \tag{2.5}$$

prime near the vector $\vec{E}$ means that this field is determined in the moving coordinate system, while the vector $\vec{A}_H$ it is determined in the fixed system. This means that the vector potential can have not only local, but also convection derivative, i.e., it can change both due to the change in the time and due to the motion in the three-dimensional changing field of this potential. This approach will lead to the new, previously not known results. In this case relationship (2.5) can be rewritten as follows:

$$\vec{E}' = -\mu \frac{\partial \vec{A}_H}{\partial t} - \mu \left(\vec{v} \nabla \right) \vec{A}_H ,$$

where $\vec{v}$ - speed of the system. Consequently, the force, which acts on the charge in the moving system, in the absence the dependence of vector potential on the time, will be written down

$$\vec{F}'_{v,1} = -\mu e \left(\vec{v} \nabla \right) \vec{A}_H \ .$$

This force depends only on the gradients of vector potential and charge rate.

the charge, which moves in the field of the vector potential $\vec{A}_H$ with the speed $\vec{v}$, possesses potential energy [1]

$$W = -e\mu \left(\vec{v} \vec{A}_H \right).$$

Therefore must exist one additional force, which acts on the charge in the moving coordinate system, namely:

$$\vec{F}'_{v,2} = -grad\ W = e\mu\ grad\left(\vec{v}\vec{A}_H\right).$$

Thus, the value $e\mu\left(v\vec{A}_H\right)$ plays the same role, as the scalar potential φ, whose gradient also gives force. Consequently, the composite force, which acts on the charge, which moves in the field of vector potential, can have three components and will be written down as

$$\vec{F}' = -e\mu\frac{\partial\vec{A}_H}{\partial t} - e\mu\left(\vec{v}\nabla\right)\vec{A}_H + e\mu\ grad\left(\vec{v}\vec{A}_H\right). \qquad (2.6)$$

The first of the components of this force acts on the fixed charge, when vector potential changes in the time and has local time derivative. Second component is connected with the motion of charge in the three-dimensional changing field of this potential. Entirely different nature in force, which is determined by last term of relationship (2.6). It is connected with the fact that the charge, which moves in the field of vector potential, it possesses potential energy, whose gradient gives force. From relationship (2.6) follows

$$\vec{E}' = -\mu\frac{\partial\vec{A}_H}{\partial t} - \mu\left(\vec{v}\nabla\right)\vec{A}_H + \mu\ grad\left(\vec{v}\vec{A}_H\right). \qquad (2.7)$$

This is a complete law of mutual induction. It defines all electric fields, which can appear at the assigned point of space, this point can be both the fixed and that moving. This united law includes and Farrday law and that part of the Lorentz force, which is connected with the motion of charge in the magnetic field, and without any exceptions gives answer to all questions, which are concerned mutual magnetoelectric induction. It is significant, that, if we take rotor from both parts of equality (2.7), attempting to obtain the first equation of Maxwell, then it will be immediately lost the essential part of the information, since. rotor from the gradient is identically equal to zero.

If we isolate those forces, which are connected with the motion of charge in the three-dimensional changing field of vector potential, and to consider that

$$\mu\ grad\left(\vec{v}\vec{A}_H\right) - \mu\left(\vec{v}\nabla\right)\vec{A}_H = \mu\left[\vec{v}\times rot\ \vec{A}_H\right],$$

that from (2.6) we will obtain

$$\vec{F}_v' = e\mu\left[\vec{v}\times rot\ \vec{A}_H\right], \qquad (2.8)$$

and, taking into account (2.4), let us write down

$$\vec{F}_v' = e\mu\left[\vec{v}\times\vec{H}\right], \qquad (2.9)$$

or

$$\vec{E}_v' = \mu\left[\vec{v}\times\vec{H}\right]. \qquad (2.10)$$

and it is final

$$\vec{F}' = e\vec{E} + e\vec{E}_v' = -e\frac{\partial\vec{A}_H}{\partial t} + e\mu\left[\vec{v}\times\vec{H}\right]. \qquad (2.11)$$

Can seem that relationship (2.11) presents Lorentz force; however, this not thus. In this relationship the field $\vec{E}$, and the field $\vec{E}_v'$ are induction: the first is connected with a change of the vector potential with time, the second is obliged to the motion of charge in the three-dimensional changing field of this potential. In order to obtain the total force, which acts on the charge, necessary to the right side of relationship (2.11) to add the term $-e\ grad\ \varphi$

$$\vec{F}_\Sigma' = -e\ grad\ \varphi + e\vec{E} + e\mu\left[\vec{v}\times\vec{H}\right],$$

where φ - scalar potential at the observation point. In this case relationship (2.5) can be rewritten as follows:

$$\vec{E}' = -\mu\frac{\partial\vec{A}_H}{\partial t} - \mu\left(\vec{v}\nabla\right)\vec{A}_H + \mu\ grad\left(\vec{v}\vec{A}_H\right) - grad\ \varphi, \qquad (2.12)$$

or, after writing down the first two members of the right side of relationship (2.12) as the derivative of vector potential on the time, and also, after introducing under the sign of gradient two last terms, we will obtain

$$\vec{E}' = -\mu\frac{d\vec{A}_H}{dt} + grad\left(\mu\left(\vec{v}\vec{A}\right) - \varphi\right). \qquad (2.13)$$

If both parts of relationship (2.12) are multiplied by the magnitude of the charge, then will come out the total force, which acts on the charge. From Lorentz force it will differ in terms of the force $-e\mu\frac{\partial\vec{A}_H}{\partial t}$. From relationship (2.13) it is evident that the value $\mu\left(\vec{v}\vec{A}\right)-\varphi$ plays the role of the generalized scalar potential. After taking rotor from both parts of relationship (2.13) and taking into account that $rot\ grad=0$, we will obtain

$$rot\ E'=-\mu\frac{d\vec{H}}{dt}\ .$$

If we in this relationship replace total derivative by the quotient, i.e., to consider that the fields are determined only in the assigned inertial system, then we will obtain the first equation of Maxwell. I.e. they arrived at that from what they began.

This examination maximally explained the physical picture of mutual induction. We specially looked to this question from another point of view, in order to permit those contradictory judgments, which occur in the fundamental works according to the theory of electricity.

Previously Lorentz force was considered as the fundamental experimental postulate, not connected with the law of induction. By calculation to obtain last term of the right side of relationship (2.11) was only within the framework STR after introducing two postulates of this theory. In this case all terms of relationship (2.11) are obtained from the law of induction, using the conversions of Galileo. Moreover relationship (2.11) this is a complete law of mutual induction, if it are written down in the terms of vector potential. And this is the very thing rule, which gives possibility, knowing fields in one reference system to calculate fields in another.

One should emphasize that in relationship (2.8) and (2.9) all fields have induction origin, and they are connected first with of the local derivative of vector potential, then by the motion of charge in the three-dimensional changing field of this potential. If fields in the time do not change, then in the right side of relationships (2.8) and (2.9) remain only last terms, and they explain the work of all existing electric generators with moving mechanical parts, including the work of unipolar generator. Relationship (2.7) gives the possibility to physically explain all composing tensions electric fields, which appears in the fixed and that moving the coordinate systems. In the case of unipolar generator in the formation of the force, which acts on the charge, two last addend right sides of equality (2.7) participate, introducing identical contributions.

With the examination of the action of magnetic field to the moving charge has already been noted its intermediary role and absence of the law of the direct action between the moving charges. Introductions of vector potential also does not give answer to this question, this potential as before plays intermediary role and does not answer a question about the concrete place of application of force.

Now let us show that the relationships, obtained by the phenomenological introduction of magnetic vector potential, can be obtained and directly from the Faraday law. With conducting of experiments Faraday established that in the outline is induced the current, when in the adjacent outline direct current is switched on or is turned off or adjacent outline with the direct current moves relative to the first outline. Therefore in general form Faraday law is written as follows:

$$\oint \vec{E}' d\vec{l}' = -\frac{d\Phi_B}{dt} . \tag{2.15}$$

This writing of law indicates that with the determination of the circulation $\vec{E}$ in the moving coordinate system, near $\vec{E}$ and $d\vec{l}$ must stand primes and should be taken total derivative. But if circulation is determined in the fixed coordinate system, then primes near $\vec{E}$ and $d\vec{l}$ be absent, but in this case to the right in expression (2.15) must stand particular time derivative. Usually in the existing literature during the record the law of magnetoelectric induction in this fact attention they do not accentuate.

Complete time derivative in relationship (2.15) indicates the independence of the eventual result of appearance EMP. In the outline from the method of changing the flow. Flow can change both due to the change $\vec{B}$ with time and because the system, in which is measured the circulation $\oint \vec{E}' d\vec{l}'$, it moves in the three-dimensional changing field $\vec{B}$. The value of magnetic flux in relationship (2.15) is given by the expression

$$\Phi_B = \int \vec{B}\, d\vec{s}' , \tag{2.16}$$

where the magnetic induction $\vec{B} = \mu \vec{H}$ is determined in the fixed coordinate system, and the element $d\vec{s}'$ is determined in the moving system. Taking into account (2.15), we obtain from (2.16)

$$\oint \vec{E}' d\vec{l}' = -\frac{d}{dt}\int \vec{B}\, d\vec{s}' .$$

and further, since $\frac{d}{dt} = \frac{\partial}{\partial t} + \vec{v}\ grad$, let us write down

$$\oint \vec{E}' d\vec{l}' = -\int \frac{\partial \vec{B}}{\partial t}\, d\vec{s}' - \int \left[\vec{B} \times \vec{v} \right] d\vec{l}' - \int \vec{v}\ div\vec{B}\, d\vec{s}' . \tag{2.17}$$

In this case contour integral is taken on the outline $d\vec{l}'$, which covers the area of $d\vec{s}'$. Let us immediately note that entire following presentation will be conducted under the assumption the validity of the Galileo conversions, i.e., $d\vec{l}' = dl$ and $d\vec{s}' = d\vec{s}$. From (2.17) follows the well known result

$$\text{of } \vec{E}' = \vec{E} + \left[\vec{v} \times \vec{B}\right], \tag{2.18}$$

from which follows that during the motion in the magnetic field the additional electric field, determined by last term of relationship appears (2.18). Let us note that this relationship is obtained not by the introduction of postulate about the Lorentz force, or from the conversions of Lorenz, but directly from the Faraday law, moreover within the framework of the Galileo conversions. Thus, Lorentz force is the direct consequence of the law of magnetoelectric induction.

The relationship follows from the Ampere law

$$\vec{H} = rot\ \vec{A}_H .$$

Then pour on relationship (2.17) for those induced it is possible to rewrite

$$\vec{E}' = -\mu \frac{\partial A_H}{\partial t} + \mu\left[\vec{v} \times rot\ \vec{A}\right],$$

and further

$$\vec{E}' = -\mu \frac{\partial \vec{A}_H}{\partial t} - \mu\left(\vec{v}\nabla\right)\vec{A}_H + \mu\ grad\left(\vec{v}\vec{A}_H\right). \tag{2.19}$$

Again came out relationship (2.7), but it is obtained directly from the Faraday law. True, and this way thus far not shedding light on physical nature of the origin of Lorentz force, since the true physical causes for appearance and magnetic field and vector potential to us nevertheless are not thus far clear.

With the examination of the forces, which act on the charge, we limited to the case, when the time lag, necessary for the passage of signal from the source, which generates vector potential, to the charge itself was considerably less than the period of current variations in the conductors. Now let us remove this limitation.

The second Maxwell equation in the terms of vector potential can be written down as follows:

$$\text{of } rot\ rot\vec{A}_H = \vec{j}\left(\vec{A}_H\right), \tag{2.20}$$

where $\vec{j}(\vec{A}_H)$ - certain functional from $\vec{A}_H$, depending on the properties of the medium in question. If is carried out Ohm's law $\vec{j} = \sigma\vec{E}$, then

$$\vec{j}(\vec{A}_H) = -\sigma\mu \frac{\partial \vec{A}_H}{\partial t} \quad . \tag{2.21}$$

For the free space relationship (2.20) takes the form:

$$\vec{j}(\vec{A}_H) = -\mu\varepsilon \frac{\partial^2 \vec{A}_H}{\partial t^2}. \tag{2.22}$$

For the free charges, which can move without the friction, functional will take the form

$$\text{of } \vec{j}(\vec{A}_H) = -\frac{\mu}{L_k}\vec{A}_H, \tag{2.23}$$

where $L_k = \frac{m}{ne^2}$ - kinetic inductance of charges. In this relationship m, e and n - mass of charge, its value and density respectively.

Of relationship (2.21 - 2.23) reflect well-known fact about existence of three forms of the electric current: active and two reactive. Each of them has characteristic dependence on the vector potential. This dependence determines the rules of the propagation of vector potential in different media. Here one should emphasize that the relationships (2.21 - 2.23) assume not only the presence of current, but also the presence of those material media, in which such currents can leak. The conduction current, determined by relationships (2.21) and (2.23), can the leak through the conductors, in which there are free current carriers. Permittance current, either bias current, can pass through themselves free space, or dielectrics. For the free space relationship (2.20) takes the form:

$$rot\ rot\vec{A}_H = -\mu\varepsilon \frac{\partial^2 \vec{A}_H}{\partial t^2}.$$

This wave equation, which attests to the fact that the vector potential can be extended in the free space in the form of plane waves, and it on its informativeness does not be inferior to the wave equations, obtained from Maxwell equations.

Everything said attests to the fact that in the classical electrodynamics the vector potential has important significance. Its use shedding light on many physical phenomena, which previously were not intelligible, or excludes the need of using Maxwell equations.