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About non-radiation of a charge moving with acceleration and "free" electromagnetic field

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Abstract
In this brief note we discuss some ambiguities in the description of the process of radiation of an accelerated charge and in the description of the so-called "free" electromagnetic (*electric*) field.

Keywords: non-radiation of an accelerated charge, free electric field

Introduction

As the beginning of this article, we would like to quote the important words of Duhem:
"... *Excessive admiration for Maxwell's work led many physicists to the opinion that it does not matter whether a theory is logical or absurd, all that needs to be done is to suggest experiments: the day will come, I am sure, when it will be recognized: bring classification and order into the chaos of facts shown by experience. Logic can be patient because it is eternal.* " [1].
Recall how theoretical physics came to the idea that an accelerated charge should radiate? The vast majority of textbooks and monographs on classical electrodynamics begin to consider the process of radiation of electromagnetic waves, starting with the study of the behavior of *an electric dipole*.
Then, having received a formula for the full radiation of a dipole, ignore the fixed dipole charge, usually located at the origin of coordinates, and apply this formula to the moving second charge of the dipole. As an example, consider the Landau textbook [2]: unlike other books, it more honest asserts that charges *can* radiate only if they move with acceleration, but *should not*! Landau finds for full radiation dipole

$$I = \frac{2}{3c^3}\ddot{\mathbf{d}}^2. \qquad (1L)$$

Then he writes [2]: "*If we have only one charge moving in an external field, then* $\mathbf{d} = e\mathbf{r}$ *and* $\ddot{\mathbf{d}} = e\mathbf{w}$, *where* $\mathbf{w}$ *is the charge acceleration. Thus* (Landau writes) *the full radiation of a moving charge*":

$$I = \frac{2e^2w^2}{3c^3}. \qquad (2L)$$

It is here that hides a deep *logical* error! The fact is that $\mathbf{w} = \ddot{\mathbf{r}}$ is *initially*, the acceleration of the change in the vector $\mathbf{r}$ of the *intra-dipole distance*, and not the acceleration of the moving charge. Of course, if one of the dipole charges is at rest, then in this case $\mathbf{w}$ is the acceleration of the moving charge. But Landau [2] uses the following definition of the dipole moment of a charge system

$$\mathbf{d} = \sum e_a\mathbf{r}_a\,, \qquad (3L)$$

Where the origin is *anywhere* within the charge system (this means that also at the point where there is no *any* charge), and the radius vectors of different charges are equal to $\mathbf{r}_a$. Then Landau determines the dipole moment of two charges (positive and negative)

$$\mathbf{d} = e\mathbf{R}_{+-} \qquad (4L)$$

Where $\mathbf{R}_{+-}$ is the radius vector from the center of the negative to the center of the positive Charge. Let us return to the logical error mentioned above. Having obtained equation (1L), Landau [2] estimates the amount of energy emitted by *a system of charges* per unit time into an element of solid angle do

$$dI = \frac{1}{4\pi c^3}\left(\ddot{\boldsymbol{d}}\times\mathbf{n}\right)^2 do = \frac{\ddot{\mathbf{d}}^2}{4\pi c^3}\sin^2\theta\, do. \qquad (5L)$$

The fact is that the radiation intensity (5L) is obtained for a complex of charges (*for the dipole* $\mathbf{R}_{+-}$ in our case), and not for a single charge! However, the question arises: *why is it then generally accepted* that it is the accelerated charge that radiates electromagnetic energy (electromagnetic waves), and not a dipole, considered as a kind of single entity? In connection with the foregoing, I believe that an electric dipole is the most fundamental concept of electromagnetism from the point of view of electromagnetic radiation than is one electric charge. Note that, *perhaps*, not every time-varying dipole radiates, but *only one* whose *module* of the dipole moment changes with time with acceleration, which is *not entirely clear* from equations (1L) and (2L). Indeed, the scalar square of a vector is equal *to the square of its length (or module)*. But what about I Tamm from [3]: "From the point of view of electronic theory, the simplest form of implementation of an oscillator is the combination of one electron and one proton, *the mutual distance of which* periodically varies with time." That is, the motion of an electron around a proton is not a "implementation of an oscillator" according to Tamm [3], *if* it *is circular with preservation the distance* between the proton and the electron, because the mutual distance between the proton and the electron is *constant* in time! This *would mean*, for example, that the generally accepted opinion that a classical hydrogen atom in which an electron moves in a *circular* (*non-elliptic*) orbit should emit is wrong!

In the framework of classical electrodynamics, the answer on the question also remains unclear: *does the charge accelerated by a non-electromagnetic way radiate*? Let us postpone this question for the time being and briefly analyze the attempt of E. Purcell [4] to visually explain the radiation of an accelerated charge based on consideration of the force lines of the field of an accelerating charge. However, we note that Purcell in [4] "accelerates" the charge by *some kind* of force (by "*something*"!), not necessarily electromagnetic one. Thus, Purcell (if he is right in his reasoning) answers the question: does the radiation, accelerated by non-electromagnetic method, radiate? We see that, according to Purcell, such an accelerated charge *radiates*! But what Purcell considers "*similar to a propagating wave of a transverse electric field (transverse to the direction of propagation)*" [4] is deeply not true, if only because this field *is not free* (which is the field of any electromagnetic wave or its electrical part according to Maxwell's theory), but begins (or ends) on the accelerated charge under discussion! That is, the question of how a connected electric field of a charge or dipole "turns" into a free one or, in other words, how a "free" electric field arises (and indeed a magnetic field not tied to a magnet or current) remains unanswered so far... So, we conclude that a single accelerated charge does not radiate a free electromagnetic field, and the radiation produces an oscillating dipole, the modulus of the moment of which varies with time. Thus, we remove the well-known problem of the so-called *electron self-acceleration*, if our reasoning is correct and the accelerated electron *does not radiate*!

The electric field created by an arbitrarily moving charge is given by the following expression derived directly from the potentials of Liénard and Wihert [2, 4]:

$$\mathbf{E}(\mathbf{R},t) = q\frac{\left(\mathbf{R} - R\frac{\mathbf{v}}{c}\right)\left(1 - \frac{v^2}{c^2}\right)}{\left(R - \mathbf{R}\frac{\mathbf{v}}{c}\right)^3} + q\frac{\left\{\mathbf{R}\times\left[\left(\mathbf{R} - R\frac{\mathbf{v}}{c}\right)\times\frac{\dot{\mathbf{v}}}{c^2}\right]\right\}}{\left(R - \mathbf{R}\frac{\mathbf{v}}{c}\right)^3} \qquad \text{(L-W)}$$

Where $\mathbf{R}$ is the vector directed from the charge to the observation Point. All values in the right part are taken at the moment of time $t_0 = t - \tau$, where τ is the delayed time. In the well-known textbook [5], the authors, in my opinion, do not reasonably sufficiently assert that the second term in Eq. (L-W) "does it mean that it is a contributor to energy flux over a large sphere because it is of order 1/R".

But now let us try to understand *what is generally emitted* by an oscillating dipole? That is, let us talk about the so-called "free" electromagnetic field or "radiation field". To do this, let us turn to [6]. I think it necessary to briefly (but possibly detail) state the main idea of the article [6], one of whose authors I am: So, it is well known that the set of four Maxwell equations (ME) [2, 5]. describes various phenomena in accordance with specific initial and boundary conditions (BC). Within the framework of our task, we are exploring here the meaning of ME solutions in regions of space with zero charge density ($\varrho = 0$).

Usually, $\varrho = 0$ at each point of the whole space represents "empty space" (see, for example, [2]. or [5]). Under this condition, both equations (5) and (6) (see below) describe solenoidal fields, which means that the electric and magnetic fields (**E** and **H**) in this area of space are transverse to the instantaneous direction of propagation. Moreover, since there are no charges in such a region, the electromagnetic wave corresponds to the so-called free field, the flow lines of which do not begin and end with a charge. Note that there is uncertainty [1]. in the definition of the so-called free electric field in textbooks and monographs. For example, on the one hand, in [2]. (§ 46) it can be found that nonzero solutions of the so-called free Maxwell equations assume that we can assert that a moving electric field can exist that is not associated with a charge. On the other hand, in [7]. (§97) it is stated that bias currents $\left(\frac{1}{c}\frac{\partial \mathbf{E}}{\partial t}\right)$ cannot exist independently of the movement of charges. In turn, it was also proved in [2]. (§62) that the field emitted by a system of moving charges depends on these charges (retarded potentials). Let us clarify this situation. Consider inhomogeneous wave equations in potential form

$$\Delta\mathbf{A} - \frac{1}{c^2}\frac{\partial^2\mathbf{A}}{\partial t^2} = -\frac{4\pi}{c}\mathbf{j}\,, \qquad (1)$$

$$\Delta\varphi - \frac{1}{c^2}\frac{\partial^2\varphi}{\partial t^2} = -4\pi\varrho\,, \qquad (2)$$

Now consider the general solutions of these equations [2] [2].

$$\varphi = \int \frac{\varrho(t - R/c)}{R}\,dV + \varphi^*, \qquad (3)$$

$$\mathbf{A} = \int \frac{\mathbf{j}(t - R/c)}{R}\,dV + \mathbf{A}^*, \qquad (4)$$

Where φ^* and $\mathbf{A}^*$ are general solutions of (1), (2) without the right part.

These solutions (Without φ^* and $\mathbf{A}^*$) represent the field created by the system, and φ^* and $\mathbf{A}^*$ must be taken equal to the external field acting on the system. Note that in any textbooks and monographs [3] the fields φ^* and $\mathbf{A}^*$ are identified with the radiation incident on the system. The system in question consists of moving charges and fields that arise when charges move within an arbitrary and fixed volume V. In other words, the components of the field φ^* and

1 Better to say "confusion"!

2 Equations (62.9) and (62.10) in [2].

3 See, for example, the text at the end of §62 [2].

$\mathbf{A}^*$ do not depend on the Currents $\mathbf{j}$, that is, this field cannot be associated with moving charges. In the terminology adopted in the traditional approach, this is the so-called *free field*. Then the question arises: *where did the field* $\{\}^*$ *come from*? When finding the answer, we can assume that this field is created by currents that are located outside our system. However, this is not the only offer, because no one will forbid us to insert these currents into our system. Thus, using once again equations (3) and (4), we obtain another solution for $\{\}^*$, which in no way depends on the currents of our new system, as was assumed in the previous case! We can continue this argument infinitely (i.e. $V \to \infty$). Then, after the integration has been extended to the whole space, there will be no room for external sources used in the traditional approach to justify the concept of a free field. In other words, *how did this free field* $\{\}^*$ *appear*? This may mean that the free field either does not exist, or always exists, and it cannot be created by any current!

We argue that such an interpretation of the "free field" does not fully correspond to the physics behind EM. We critically review the usual interpretation in order to find that $\varrho = 0$ does not lead to the obligatory existence of a free electric field. In CGS units, Maxwell's equations are:

$$\nabla \cdot \mathbf{E} = 4\pi\varrho \,, \tag{5}$$

$$\nabla \cdot \mathbf{H} = 0 \,, \tag{6}$$

$$\nabla \times \mathbf{H} = \frac{4\pi}{c}\mathbf{j} + \frac{1}{c}\frac{\partial \mathbf{E}}{\partial t} \,, \tag{7}$$

$$\nabla \times \mathbf{E} = -\frac{1}{c}\frac{\partial \mathbf{H}}{\partial t} \,. \tag{8}$$

Conservation of charge is provided by the standard continuity condition:

$$\nabla \cdot \mathbf{j} + \frac{\partial \varrho}{\partial t} = 0 \,. \tag{9}$$

We considered in [6]. three types of areas: (i) an "isolated free" area where the resulting electric field with flow lines that either start or end with charge is zero at each point, for example, inside a hollow conductor of any shape or free universe; (ii) a "non-isolated free" region where this electric field [(see (i)] is non-zero at every point; and (iii) a charge-neutral "region where point charges exist but their algebraic sum is zero. As a rule, [4]. $\varrho = 0$ is set in (5) and (7) in the *whole* space (or in the "isolated charge-free" region, see (i)) and equations are obtained for the free field. We assert here that this simple procedure does not lead strictly to a free solution of the EM. For our reasoning, it is important to recall how equations (5) and (7) are obtained in the usual approach. We introduce the vectors $\mathbf{E}_0$ and $\mathbf{E}^*$. The vector $\mathbf{E}_0$ is an electric field with flow lines that either begin or end with a charge; the vector $\mathbf{E}^*$ represents some free field for which the flow lines do not begin and end with a charge. According to Gauss's law [2]: the electric field flux $\mathbf{E}_0$ through any closed surface, i.e., the integral $\oint \mathbf{E}_0 \cdot d\mathbf{a}$ over the surface, is 4π times the total charge enclosed by the surface:

$$\oint_S \mathbf{E}_0 \cdot d\mathbf{a} = 4\pi Q = 4\pi \textstyle\sum_i q_i = 4\pi \int_V \varrho dV. \tag{10}$$

This statement is equivalent to the Coulomb law, and it could be taken equally well as the basic law of electrostatic interactions, after determining the charge field. In other words, the laws of Gauss and Coulomb are not independent physical laws, but the same law, expressed differently. We note this well-known fact that the proof of equation (10) depended on the *inverse-square* nature of the interaction, and therefore the Gauss theorem (law) in physics makes sense *only* for reverse-square fields [5]. In this regard, I would like to emphasize two aspects:

(a) The Coulomb law is defined in terms of the individual q_i, so the expression for charge Q (equation (10)) in terms of charge density ϱ is strictly valid as a limit when there is a very large number of charges. (It can be added that, ϱ of course, can be considered as a δ -function).

b) The right-hand sides of equation (10) can be zero in two different ways: (*) *The condition is without charge*, $Q = 0$, when $q_i = 0$, for all "i". (**) *The condition of the neutral charge*, $Q = 0$ for $q_i \neq 0$, for all "i" is independent.

From the mathematical point of view, for the cases (*) and (**), one should not expect the same solution for the value of the electric field $\mathbf{E}_0$ according to Gauss' law (10). Indeed, for *an isolated* no-charge zone, the *only* solution

$$\mathbf{E}_0 = 0 \,, \tag{11}$$

Which simply means that a non-existent charge cannot produce an electric field $\mathbf{E}_0$. Note that the previous statement is qualitatively different from the fact that there is an electric field in the region that vanishes at $\varrho = 0$.

We now recall the formulation of the Ostrogradsky-Gauss theorem. Being fair for each vector field, it is certainly valid for $\mathbf{E}_0$:

$$\oint_S \mathbf{E}_0 \cdot d\mathbf{a} = \int_V \nabla \cdot \mathbf{E}_0 dV \,. \tag{12}$$

Both equations (10) and (12) are performed for any volume, so we can choose any shape, size or location. Comparing them, we see that this can only be true if at each point

$$\nabla \cdot \mathbf{E}_0 = 4\pi\varrho \,. \tag{13}$$

[4] In (7) $\varrho \mathbf{V} = \mathbf{j}_{cond}$.

[5] Or a superposition of such fields.

In an isolated charge-free zone, ϱ is by definition zero. Thus, $\nabla \cdot \mathbf{E}_0$ is automatically zero at every point in the space of this region, since $\mathbf{E}_0$ in this region is zero.
Now recall the origin of the displacement current term in equation (7). Indeed, Maxwell discovered his famous paradox: without this term, equation (7) is incompatible with continuity equation (9):

$$\nabla \times \mathbf{H} = \frac{4\pi}{c}\mathbf{j}_{\text{cond}} + (?), \tag{14}$$

So the member (?) Is $\mathbf{j}_{\text{disp}}$, and it must satisfy:

$$\nabla \times \mathbf{H} = \frac{4\pi}{c}\mathbf{j}_{\text{tot}} = \left(\mathbf{j}_{\text{cond}} + \mathbf{j}_{\text{disp}}\right), \tag{15}$$

$$\nabla \cdot \mathbf{j}_{\text{tot}} = \nabla \cdot \mathbf{j}_{\text{cond}} + \nabla \cdot \mathbf{j}_{\text{disp}} = 0, \tag{16}$$

$$\nabla \cdot \mathbf{j}_{\text{disp}} = \frac{1}{4\pi}\frac{d}{dt}\nabla \cdot \mathbf{E}_0 = \nabla \cdot \left(\frac{1}{4\pi}\frac{d\mathbf{E}_0}{dt}\right). \tag{17}$$

Using (13), we obtain

$$\nabla \cdot \mathbf{j}_{\text{disp}} = \frac{1}{4\pi}\frac{d}{dt}\nabla \cdot \mathbf{E}_0 = \nabla \cdot \left(\frac{1}{4\pi}\frac{d\mathbf{E}_0}{dt}\right). \tag{18}$$

The general solution of this equation

$$\mathbf{j}_{\text{disp}} = \frac{1}{4\pi}\frac{d\mathbf{E}}{dt} + \nabla \times \{\mathbf{F}_1(x,y,z,t)\} + \mathbf{F}_2(t) + const, \tag{19}$$

Where $\mathbf{F}_{1,2}$ are arbitrary Vectors.
In the usual approach, all additional time-dependent members, but not time derivatives, are set to zero without special consideration:

$$\nabla \times \{\mathbf{F}_1(x,y,z,t)\} + \mathbf{F}_2(t) + const = 0\,. \tag{20}$$

This is the easiest way to get equation (7). Then, having received equation (7), the next step (attention!) Is usually done to establish the Maxwell equations for a free field (see, for example, [2], §46):

$$\nabla \cdot \mathbf{E}_0 = 0\,, \tag{21}$$
$$\nabla \cdot \mathbf{H} = 0\,, \tag{22}$$

$$\nabla \times \mathbf{H} = \frac{1}{c}\frac{\partial \mathbf{E}_0}{\partial t}\,, \tag{23}$$

$$\nabla \times \mathbf{E}_0 = -\frac{1}{c}\frac{\partial \mathbf{H}}{\partial t}\,. \tag{24}$$

However, as we have already seen, the value $\varrho = 0$ *in the whole space* is equivalent to imposing *a no-charge condition* (when $q_i = 0$ for all i). Strictly speaking, this only corresponds to *an isolated* area without charges and completely without a field:

$$\nabla \cdot \mathbf{E}_0 = 0\,, \tag{25}$$

$$\nabla \cdot \mathbf{H} = 0\,, \tag{26}$$

$$\nabla \times \mathbf{H} = (?)\,, \tag{27}$$

$$\nabla \times \mathbf{E}_0 = 0\,. \tag{28}$$

In other words, the value of the electric field $\mathbf{E}_0$ must be zero at each point in this region. However, we must emphasize here that for nonzero field values (the flow lines of this field begin or end with charges). (21) - (24) make sense in the case of a non-isolated charge-free zone, as well as in the case of a region with a neutral [6].
Let us now, however, make a very important remark:
Regardless of the formulation of the boundary value problem for the Maxwell equations, it is obvious that the Gauss law (10) is invariant with respect to any additional vector field $F^*_{\text{add}}(x,y,z,t)$ for which flow lines do not begin and end with charge (for this vector $\nabla \cdot F^*_{\text{add}} = 0$ at *each* point of the *whole* space by definition).
In the usual approach, this term with zero divergence is identified with the free electric field $\mathbf{E}^*$ in the approximation, when the charges and currents are very far from the area under consideration. According to this usual procedure, the free field was not derived from the basic equations, but introduced as an arbitrary term that satisfies the Gauss law (10) or (13). In other words, we can only *postulate* the existence of a free field $\mathbf{E}^*$. In this case, instead of equations (21)-(24), repeating the calculations (14)-(19), we obtain *another* displacement current $\frac{1}{4\pi}\frac{\partial \mathbf{E}^*}{\partial t}$.

Then, by setting $\varrho = 0$ in the whole space, one obtains

$$\nabla \cdot \mathbf{E}^* = 0\,, \tag{29}$$

$$\nabla \cdot \mathbf{H} = 0\,, \tag{30}$$

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[6] Note that in this way it is possible to resolve the Maxwell paradox without introducing any field that is not associated with a charge, that is, without introducing a “free field”! Actually, in this case, the Maxwell equation (7) is written as (for one moving particle [6]):

$$\nabla \times \mathbf{H} = \frac{4\pi}{c}q\delta\left(\mathbf{r} - \mathbf{r}_q(t)\right)\mathbf{V} - \frac{1}{4\pi}(\mathbf{V}\cdot\nabla)\mathbf{E}_0.$$

(Obviously, $\delta\left(\mathbf{r} - \mathbf{r}_q(t)\right)$ in the “non-isolated charge-free zone” will be zero). So, the Maxwell paradox is resolved, but it is obvious that the "free" electric field $\mathbf{E}^*$ cannot be a solution of this equation by definition.

$$\nabla \times \mathbf{H} = \frac{1}{c}\frac{\partial \mathbf{E}^*}{\partial t}, \qquad (31)$$

$$\nabla \times \mathbf{E}^* = -\frac{1}{c}\frac{\partial \mathbf{H}}{\partial t}. \qquad (24)$$

Although the (free) field $\mathbf{E}^*$ certainly satisfies Maxwell's equations, *it is not a consequence of Maxwell's equations* (contrary to the generally accepted point of view) [7].

Summarizing the above, I would like to recall *the generally accepted* point of view that due to the accelerated (or, in particular, oscillating) movement of the charges that make up a radiating globally neutral source, the flow lines of the electric field *leave* the charges *closed* by themselves and form *a free*, gradually spreading (towards infinity) electromagnetic field.

Unfortunately, this reasoning is nothing more than words that are not supported by mathematical formulas. In this regard, it is well known that in classical electrodynamics *there is no* mathematical approach for describing the process of "*leaving*" and "*closing*" (see, for example, the expression 63.8 for the electric field obtained from the Lienard-Wihert potentials [2]). It is well known that the "Coulomb" part of the field (1), as well as the "accelerated" part, cannot be described by a flow of lines that are not associated with a charge (in the conventional interpretation, these lines are "closed" near the surface of the charge and then leave the near zone, already "cut off" from the charge). It was shown in [6] that the absence of this mechanism in the framework of the traditional theory is not a mere coincidence or an accident. As a matter of fact, in accordance with a rigorous mathematical interpretation of Maxwell's equations (without any approximation), this mechanism cannot exist for a full electric field.

Thus, within the framework of Maxwell's theory, the free field can be understood only as a valid approximation for regions far from charges and currents, but not as an adequate concept in itself. Many physicists may ignore this fact (as they are accustomed to working with approximation). Thus, within the framework of Maxwell's theory, the free field can be understood only as a valid approximation for regions far from charges and currents, but not as *an adequate concept in itself*. Many physicists may ignore this fact (as they are accustomed to working with approximation). Nevertheless, it is important to find out this subtle point where this approximation (by the way, also accepted for quantum electrodynamics) is no longer valid. The explanation of these moments can give us additional information about the limitations and hidden difficulties of the classical electromagnetic theory (which, as is well known, has recently been questioned, see, for example [8]). In this article I also hope to understand: is it possible to improve Maxwell's theory without or with a modification of its basic equations. It turns out you can! And O. D. Jefimenko in his books [9] and [10] did it! So what is the electromagnetic field in a vacuum?

As it was shown in [9] and [10], the cause-effect equations for the electric and magnetic fields in vacuum are

$$\mathbf{E} = \frac{1}{4\pi\varepsilon_0}\int\left\{\frac{[\varrho]}{r^2} + \frac{1}{rc}\left[\frac{\partial\varrho}{\partial t}\right]\right\}\mathbf{r}_u dV' - \frac{1}{4\pi\varepsilon_0 c^2}\int\frac{1}{r}\left[\frac{\partial\mathbf{J}}{\partial t}\right]dV' \qquad (\text{Jef.}1)$$

And

$$\mathbf{H} = \frac{1}{4\pi}\int\left\{\frac{[\mathbf{J}]}{r^3} + \frac{1}{r^2 c}\left[\frac{\partial\mathbf{J}}{\partial t}\right]\right\}\times\mathbf{r}_u dV', \qquad (\text{Jef.}2)$$

where the square brackets in these equations are the symbol of retardation, indicating that the values between the brackets should be estimated at time $t' = t - r/c$, where t is the time for which $\mathbf{E}$ and $\mathbf{H}$ are estimated, ϱ is the electric charge density, c is the speed light, r is the distance between the point of the field x, y, z (the point for which $\mathbf{E}$ and $\mathbf{H}$ are evaluated) and the source point x', y', z' (volume element dV'), and $\mathbf{r}_u$ is the unit vector directed from dV' to the field point, $\mathbf{J}$ – current density. The integrals in both equations are calculated over the entire space.

It can be seen from these equations that the electric field has *three* causal sources: charge density ϱ, the time derivative of ϱ and the time derivative of $\mathbf{J}$. In addition, one can see that the magnetic field has *two* causal sources: the electric current density and the time derivative from $\mathbf{J}$. According to these equations, in systems with a variable time, electric and magnetic fields are always created simultaneously, since they have a common causal source: a changing electric current [the last term of the equation (Jef.1) and the last term in the integral of the equation (Jef.2)]. After creation, the two fields coexist since then without any influence on each other. Therefore, electromagnetic induction as a phenomenon in which one of the fields creates another, is *an illusion*. The illusion of "mutual creation" arises from the fact that in time-dependent systems, both fields always seem noticeable together, while their pathogens (alternating current in particular) remain in the background. In fact, equations (Jef.1) and (Jef.2) are expressions for the *radiated* electric and magnetic fields in a vacuum!

The electric field created by time-varying currents is very different from all other fields encountered in electromagnetic phenomena. O. D. Efimenko in [9] and [10], given that the cause of this field is the movement of electric charges (current), gives it a special name *electrokinetic field* and the force that this field has on an electric charge, *electrokinetic force*. Of course, you can just call this field "induced field". However, such a designation will not reflect the special character and properties of this field. Note, however, that the term "electrokinetic" is also used in relation to phenomena associated with the movement of charged particles through a continuous medium or with the movement of a continuous medium over a charged surface. These phenomena are not related to the electrokinetic field defined in [9] and [10]. Another suitable name for this field is the Faraday Field, introduced by P. Beckmann in [11]. Jefimenko denotes the electrokinetic field by the Vector $\mathbf{E}_k$. From the equation (Jef.1), we have

[7] *Any non-electric* field of zero divergence *also* satisfies Maxwell equations!

$$\mathbf{E}_k = -\frac{1}{4\pi\varepsilon_0 c^2}\int \frac{1}{r}\left[\frac{\partial \mathbf{J}}{\partial t}\right] dV'. \qquad (27)$$

In conclusion of my article, I note that the author of the present article predicted the existence of *electric* (*non-electromagnetic*!) radiation [12], namely, *waves* of an *electrokinetic* field, which is a solution to the equation

$$\nabla^2 \mathbf{E}_k - \frac{1}{c^2}\frac{\partial^2 \mathbf{E}_k}{\partial t^2} = \mu_0 \frac{\partial \mathbf{J}}{\partial t} \qquad (28)$$

It is *this field* that can qualify for the term "free" electric field, as it does not *initially* begin or end on an electric charge!

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