Do We Understand the Field Transformations in Classical Electrodynamics?

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This paper considers a number of physical problems, dealing with transformation of the non-radiating electric and magnetic fields between different inertial frames, and analyses an origin of these fields through their sources and the laws of electrostatics and magnetostatics. It has been found that, in all problems of classical electrodynamics dealing either with single space-time transformations or with successive space-time transformations with collinear velocities, a relationship between the fields and their sources in terms of the electrostatic and magnetostatic laws can be established. In problems dealing with successive field transformations with non-collinear relative velocities, relativity theory fails to indicate an origin of the fields obtained formally via such transformations. This can be done in covariant ether theories, and some physical inferences from the obtained results are discussed.

Keywords: Field transformations, special relativity, covariant ether theories

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1. Introduction

It is well known that a transformation of anti-symmetrical 4-tensor of the electromagnetic (EM) field

$$F_{ik} = \frac{\partial A_k}{\partial x^i} - \frac{\partial A_i}{\partial x^k} \tag{1}$$

gives the following expressions for transformation of the electric $\vec{E}$ and magnetic $\vec{B}$ fields, in the case where the relative velocity $\vec{v}$ of two inertial reference frames K and K' is parallel to the axis x [1]:

$$E_x = E'_x, \tag{2a}$$

$$E_y = \frac{E'_y + vB'_z}{\sqrt{1 - v^2/c^2}}, \tag{2b}$$

$$E_z = \frac{E'_z - vB'_y}{\sqrt{1 - v^2/c^2}}, \tag{2c}$$

$$B_x = B'_x, \tag{2d}$$

$$B_y = \frac{B'_y - vE'_z/c^2}{\sqrt{1 - v^2/c^2}}, \tag{2e}$$

$$B_z = \frac{B'_z + vE'_y/c^2}{\sqrt{1 - v^2/c^2}}, \tag{2f}$$

These transformations imply a relativity of the electric and magnetic fields in different inertial reference frames. In this paper we focus our attention only on the non-radiating EM fields, which are always attached to their sources (moving charges, characterized by the charge

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density r and current density $\vec{j}$, which are also transformed between different inertial frames). Hence, in order to fully understand the physics of transformations (2), we have to find an origin of the EM fields detected by different inertial observers, through the r and $\vec{j}$ parameters. Establishment of these relationships for some physical problems is the goal of present paper. Section 2 analyses a number of selected problems of classical electrodynamics, where the field transformations can be understood via the transformation of r, $\vec{j}$ for different inertial observers. We shall reach the conclusion that a relationship between $\vec{E}$, $\vec{B}$ and r, $\vec{j}$ can be established in special relativity theory (SRT) for those problems dealing either with single field transformations or with successive field transformations with collinear velocities. However, when the relative velocities are not collinear, the non-commutativity property of field transformations makes it impossible to interpret the obtained electric and magnetic fields through their sources. A physical problem of such a kind (motion of a charged particle perpendicular to a straight wire carrying current) is considered in Section 3 within covariant ether theories, which provide its consistent physical explanation. Section 4 presents a contradiction between the law of transformation of charge density and the law of conservation of charge, arising in relativity theory under transformation from an inertial to rotating frame. Finally, Section 5 presents some conclusions.

2. Interpretation of field transformations in relativity theory

We recall that attempts to establish an origin of the electric and magnetic fields in different inertial frames through their sources were

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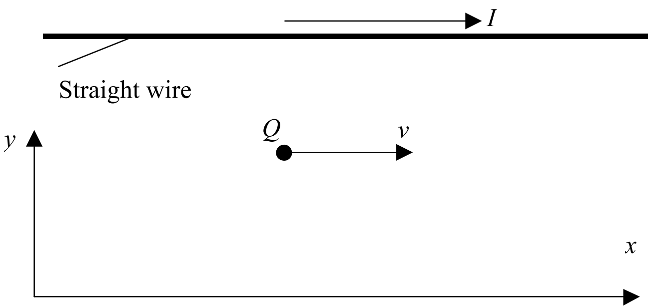

Fig. 1. A straight wire with the current *I* flowing along the axis *x*, and the probe charged particle with positive charge Q, moving at the constant velocity *v* along the axis *x*.

already made in the scientific literature. An example of this kind is shown in Fig. 1 [2].

A straight wire with the current I lies along the axis x, and a particle with the positive charge Q moves along the axis x with the velocity v at the considered instant. The length of the straight wire greatly exceeds its distance from the particle, so that other elements of the circuit with the current I do not contribute to the EM field at the location of the particle. The force acting on the particle is to be determined.

The problem is easily solved in the rest frame of the wire. The current I induces a magnetic field, which is directed in the negative z-direction at the location of particle. Hence, the Lorentz force, acting on the particle is directed along the axis y, and its value is

$$F_y = QvB . \tag{3}$$

Now we have to understand the origin of this force in the rest frame of the particle. In this frame a magnetic field from the current I is not relevant, and the force, acting on the particle, is purely

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electrical. Such a force appears due to different charge densities of positive and negative charges in the wire. Indeed, the positive ion skeleton of the wire moves at the constant velocity v opposite to the axis x, while the conduction electrons move at the velocity

$$u' = \frac{u+v}{1+uv/c^2} \tag{4}$$

opposite to the same axis. (Here u is the flow velocity of conduction electrons, constituting the current I, in the rest frame of wire). As a result, the ion skeleton of the wire contracts by $\sqrt{1-v^2/c^2}$ times, while the filament of conduction electrons contracts by $\sqrt{1-u'^2/c^2}$ times. Such a difference in the scale contraction effect leads to different charge densities for positive and negative charges of the wire. As a result, the value of charge density of electrons r_- exceeds the charge density of ions r_+, which causes the appearance of a non-vanishing electric field along the axis y in the rest frame of particle. The calculations, implemented in Ref. [2] show that the value of this electric field is

$$E_y = vB\Big/\sqrt{1-v^2/c^2}\ . \tag{5}$$

This field creates a force, acting on the particle along the axis y

$$F_y = QvB\Big/\sqrt{1-v^2/c^2}\ ,$$

in full accordance with the transformation of forces between the rest frames of wire and charged particle.

Note that the same value of electric field (5) is derived from Eq. (2b). Thus, for the problem in Fig. 1 we fully understand the transformations (2) for the electric and magnetic fields, proceeding from analysis of their sources.

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A list of physical problems, where the results of transformations (2) can be explained within SRT in relation to the sources of electric and magnetic fields in different frames of reference can be easily extended. Omitting consideration of particular examples of such a kind, we present a general classification of these problems:

- all problems, dealing with single transformation from one inertial frame to another; an example of such a problem is shown in Fig. 2;
- all problems, dealing with successive space-time transformations with collinear velocities. Fig. 1 represents an example of such a problem: the velocity $\vec{v}$ of the probe particle is collinear with the velocity $\vec{u}$ of conduction electrons in the straight wire with current;
- all problems dealing with circular currents, where the velocities of conduction electrons $\vec{u}$ do not have a designated direction with respect to the velocity of the laboratory frame (see, *e.g.*, Fig. 3).

This classification follows from a general theorem of covariant ether theories (CETs) [3]: either for single Lorentz transformations, or for successive Lorentz transformations having collinear velocities, the special relativity and an infinite set of ether theories, satisfying the general relativity principle, give the same results of calculations for any inertial observer. The mathematical basis of this theorem is that in all these theories the measured space and time coordinates obey the Lorentz transformations; and, given collinear relative velocities, successive Lorentz transformations commute with each other [3]. The same is true for the field transformations (2): in general, the successive field transformations are not commutative, but they do commute for collinear velocities.

In contrast, for non-collinear relative velocities the CETs and SRT give, in general, different predictions in space-time kinematics; in

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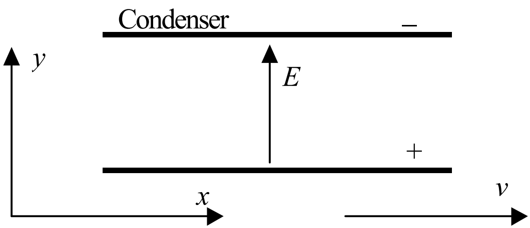

Fig. 2. A parallel plate charged condenser moves at constant velocity *v* along the axis *x* of the laboratory frame. In the rest frame of the condenser the inner electric field $\vec{E}$ is parallel to the axis *y*. According to transformation (2b), the electric field in the laboratory frame also lies along the axis *y*, and it increases $1/\sqrt{1-v^2/c^2}$ times. This happens due to the scale contraction along the axis *x*, causing the increase of the charge surface density of plates of the condenser by $1/\sqrt{1-v^2/c^2}$ times. The magnetic field in the inner volume of the condenser lies along the axis *z* (see, Eq. (2f). It is induced by the motion of charged plates along the axis *x*.

particular, with respect to the Thomas-Wigner rotation [3]. The same is true for successive field transformations with non-collinear relative velocities [4]. However, even in cases where the predictions of CETs and SRT coincide, a physically reasonable explanation of the transformations (2) within SRT cannot be found.

In order to demonstrate this assertion, let us consider the same straight line with the current *I* as in Fig. 1, but now the probe charged particle *Q* moves perpendicular to the current $\vec{I}$ along the axis *y* at the velocity -*v* at the instant considered (Fig. 4). One desires to find the force acting on the particle in the laboratory frame K and in the rest frame of the particle K_Q.

The problem is again easily solved in the laboratory frame. The magnetic field from the current *I* lies along the *z*-axis at the location

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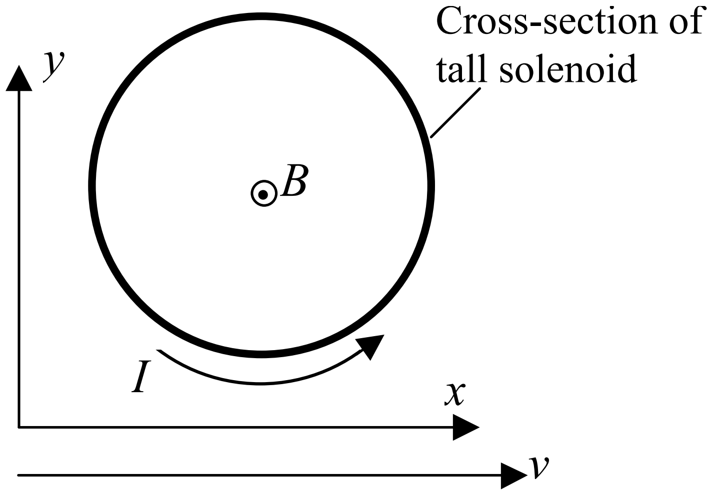

Fig. 3. The solenoid with counter-clockwise current *I* creates a constant magnetic field *B* along the axis *z* in its inner volume. The solenoid moves at the constant velocity *v* along the axis *x* of a laboratory frame. Then according to transformation (2b), an observer in the laboratory frame detects an electric field $\vec{E}$ in the *y*-direction. This result can be understood proceeding from the scale contraction effect for conduction electrons, moving at the velocities $\vec{v} \oplus \vec{u}(j)$ in the laboratory frame. (Here j is the angle coordinate along the circumference of a cross-section of the solenoid). Then one can show that the surface charge density varies harmonically with j. According to electrostatics, such a charge distribution induces a constant electric field inside the solenoid, directed along the axis *y*.

of particle, and the Lorentz force, acting on the particle, is directed at the *x*-direction. Its value is

$$F_x = QvB. \tag{6}$$

Now let us find the force acting on the particle in its rest frame K_Q. In this frame the magnetic field of the current *I* is irrelevant. The electric field can be found from transformation of the EM field, which should be modified in comparison with (2) for the case where the velocity *v* of the wire (source of EM fields) lies along the *y*-axis:

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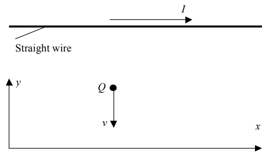

Fig. 4. The straight wire carrying current *I* and the probe charged particle with positive charge *Q*, moving at the constant velocity -*v* along the axis *y*.

$$E_x = \frac{E'_x + vB'_z}{\sqrt{1-v^2/c^2}}, \tag{7a}$$

$$E_y = E'_y, \tag{7b}$$

$$E_z = \frac{E'_z - vB'_x}{\sqrt{1-v^2/c^2}}, \tag{7c}$$

$$B_x = \frac{B'_x - vE'_z/c^2}{\sqrt{1-v^2/c^2}}, \tag{7d}$$

$$B_y = B'_y, \tag{7e}$$

$$B_z = \frac{B'_z + vE'_x/c^2}{\sqrt{1-v^2/c^2}}. \tag{7f}$$

Since in the laboratory frame only the component $B'_z = B$ is not equal to zero, the single non-vanishing component of the electric field is E_x, and its value is found from Eq. (7a):

$$E_x = vB'_z \Big/ \sqrt{1-v^2/c^2}. \tag{8}$$

This field induces the force

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$$F'_x = QvB\Big/\sqrt{1-v^2/c^2}\ , \qquad (9)$$

acting on the particle along the axis x. Eqs. (6) and (9) agree with each other with respect to the force transformation between K and K_Q.

The next (and crucial) problem is to understand the appearance of electric field (8) along the axis x. One can see that this field can be formally derived as the partial time derivative of the vector potential $\vec{A}$ from the current $\vec{I}$. However, if we want to understand its appearance in terms of its sources, that this effect is mysterious in SRT. Indeed, an electric field along the axis x appears, from the viewpoint of electrostatics, if the homogeneously charged line of positive ions (rigid skeleton of conductor) and the filament of conduction electrons are not parallel to each other, but lie at some (small) angle *a*, as shown in Fig. 5. (In general, the lines of electric fields for moving and resting charged particles differ from each other. However, this is not the case when the relative velocity is orthogonal to the axis of the wire. That is why we apply the same laws of electrostatics as for resting charges). We can estimate the angle *a* proceeding from Eq. (8), taking into account that in the laboratory frame

$$B'_z = I\big/2pe_0c^2r\ , \qquad (10)$$

(r is the distance between the wire and particle), and the electric field of the filament of conduction electrons is

$$E_y = l_{\_}\big/2pe_0r\ . \qquad (11)$$

(Here $l_{\_}$ is the negative charge per unit length). Substituting Eq. (10) into Eq. (8), one gets:

$$E_x = \frac{vI}{\sqrt{1-v^2/c^2}\,2pe_0c^2r}\ . \qquad (12).$$

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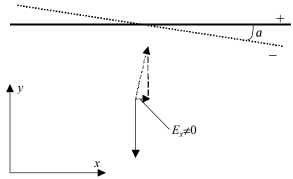

Fig. 5. A non-vanishing component along the axis of wire E_x could appear only in case the homogeneously charged line of positive ions (full line) and the filament of conduction electrons (dash line) are not parallel to each other.

Further, taking into account that

$$I = r\_uS = l\_u$$

(u is the flow velocity of conduction electrons, and S is the cross-section of the wire), we obtain to the accuracy c^{-2}, sufficient for further calculations:

$$a \approx \frac{E_x}{E_y} \approx \frac{uv}{c^2}. \tag{13}$$

However, the lattice of positive ions and conduction electrons belong to the same solid body (conductive wire), and it is senseless to consider their lines as separated by a non-vanishing angle a. Nevertheless, SRT indeed predicts an inclination of the lines of positive ions and conduction electrons for an observer in the frame K_Q due to the Thomas-Wigner rotation. Indeed, for the probe charged particle the frame K_i (rest frame of ions) moves at the constant velocity v along the axis y, and the frame K_e (attached to the conduction electrons) moves in the negative x-direction of K_i (here we take into account that the velocity u of conduction electrons is opposite to the current I). For such successive transformations $K_Q \rightarrow K_i \rightarrow K_e$, the coordinate axes of K_e and K_Q are not parallel to each other, due to the Thomas-Wigner rotation, and constitute the angle g (Fig. 6), which has the value [5]

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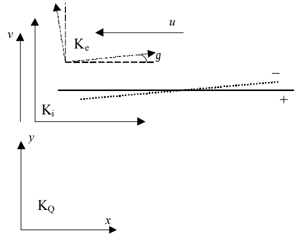

Fig. 6. Due to the Thomas-Wigner rotation the coordinate axes of the frames K_Q and K_e are not parallel to each other, and constitute the angle g, as shown.

$$g \approx \frac{uv}{2c^2}. \tag{14}$$

We see that the values of a and g differ from each other ($g = a/2$). And what is more, the signs of these angles are different (compare Figs. 5 and 6). Hence, the application of relativistic kinematics shows that the electric field E_x should be directed in the negative x-direction, while the field transformations (7) give a positive E_x. We see that the results are quite contradictory, even without any additional comment on the senseless assumption that the line of positive ions and filament of conduction electrons lie at a non-vanishing angle between each other in the frame K_Q.

In these conditions one may mention that the appearance of an electric field along the axis x in the frame K_Q is derived as $-\partial\vec{A}/\partial t$, and it follows from general transformations (7). Such an answer could be acceptable for purely mathematical, but not physical, theory; especially under recognition that the mentioned effect finds its physical explanation in other space-time theories, in particular, in covariant ether theories (CETs).

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Here we will not reproduce the analysis of CETs, this having been done in Ref. [3, 6]. Below we mention only the main points relevant for the problem considered in Fig. 4.

3. Field transformations with non-collinear relative velocities in covariant ether theories

The CETs adopt the same general principles as SRT (space-time homogeneity, space isotropy and the causality principle), but replace the Einstein relativity principle by the general relativity principle [3]. Such a set of the most general physical principles allows the existence of a preferred (absolute) frame K_0 with Galilean metrics of space-time. In any moving inertial frame the metric tensor **g** is no longer Galilean. In such a geometry the physical (true) x_{ph} and measured x_{m} space-time four-vectors, in general, differ from each other, and we separately derive their transformation rules. These transformations for two arbitrary inertial frames K' and K" have the form [3]:

$$\left(x_{\mathrm{ph}}\right)_i = A_{ij}(\vec{v}_1)[A^{-1}(\vec{v}_2)]^{jk}\left(x''_{\mathrm{ph}}\right)_k, \tag{15}$$

$$\left(x_{\mathrm{m}}\right)_i = L_{ij}(\vec{v}_1)[L^{-1}(\vec{v}_2)]^{jk}\left(x''_{\mathrm{m}}\right)_k, \tag{16}$$

under the following condition for the absolute frame K_0:

$$\left(x'_{\mathrm{ph}}\right)_i \doteq \left(x'_{\mathrm{m}}\right)_i \doteq \left(x'_{\mathrm{L}}\right)_i . \tag{17}$$

Here $\vec{v}_1, \vec{v}_2$ are the absolute velocities of the frames K and K", respectively, and **A** is any admissible linear space-time transformation.

We see that measured space-time four-vectors obey the Lorentz transformations. However, in contrast to SRT, in CETs Nature does not "know" a direct relative velocity of two arbitrary inertial frames K

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and K”: it is always composed as a sum $\vec{v}_1 \oplus \vec{v}_2$, where $\vec{v}_1$ and $\vec{v}_2$ are the corresponding velocities of K and K” in K_0.

Physical space-time is not observable in an arbitrary inertial reference frame, and we cannot determine the matrix **A** in Eq. (15) in explicit form. Thus, we are free to choose **A** in different admissible forms, obtaining in such a way the different versions of CETs. One can show [3, 6] that for the simplest choice **A**=**G**, (**G** is the matrix of the Galilean transformation), the behaviour of physical space-time is subject to the Lorentz ether postulates, which imply the absolute dilation of time and absolute contraction of moving scale along the direction of absolute velocity.

We also notice that a coincidence of physical and measured four-vectors in K_0 (Eq. (17)) makes valid the Maxwell equations in this frame, and the validity of Lorentz transforms for x_m extends applicability of classical electrodynamics to any moving inertial frame. Thus, in CETs we again use the field transformations (2) and (7).

Keeping in mind the results obtained, let us turn to the problem in Fig. 4, considering it within CETs for **A**=**G** (the Lorentz ether theory). First, we assume for simplicity that the charged particle Q rests in the absolute frame K_0, while the straight wire moves at the constant velocity v along the axis y of K_0. Then the filament of conduction electrons moves in K_0 at the constant velocity

$$\vec{V} = \vec{u} \oplus \vec{v} . \tag{18}$$

(As we mentioned above, in CETs nature “does not know” relative velocities, it operates only with absolute velocities). Let us designate the angle between the axis x and $\vec{V}$ as j (see, Fig. 7) Then, due to the absolute scale contraction effect along the vector $\vec{V}$, the axes x and y of the frame K_e change their spatial orientation with respect to the

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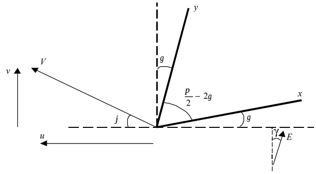

Fig. 7. Due to the absolute scale contraction effect, the components x_V and y_V along the vector of absolute velocity $\vec{V}$ reduce by $\sqrt{1-V^2/c^2}$ times, while the components $x_{\perp V}$ and $y_{\perp V}$ orthogonal to $\vec{V}$ remain unchanged. As a result, the axes *x* and *y* are rotated in opposite directions through the angle *g*, defined by Eq. (14)

axes of K_0. This effect was considered particularly in Ref. [4]. For the direction of $\vec{V}$ as shown in Fig. 7, the axis *x* of K_e is rotated through the angle *g*, defined by Eq. (14) in the counter-clockwise direction, and the axis *y* of K_e is rotated through the same angle *g* in the clockwise direction. As a result, the axes *x* and *y* make an angle $p/2-2g$ with each other in the frame K_Q. Since in the frame K_e the filament of conduction electrons is directed along the axis *x*, and the electric field $\vec{E}$ is collinear to the axis *y*, in the absolute frame this filament (if it were mechanically free) should be rotated through the angle g in the counter-clockwise direction, and the vector $\vec{E}$ should be rotated through the same angle in the clockwise direction (Fig. 8)*. As a result, we obtain a true (positive) sign for the projection of the electric field $\vec{E}$ on the axis *x*. At the same time, the angle *g* is half the

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* One can show that the same direction of the electric field is obtained from the field transformation for the velocity $\vec{V} = \vec{u} \oplus \vec{v}$ between K_e and K_Q.

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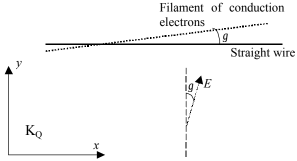

Fig. 8. Position of the filament of conduction electrons (in the hypothetical case when it is mechanically free) and its electric field $\vec{E}$ (dashed lines).

required angle *a*, obtained from the field transformations (7) between K_i and K_Q (compare Eqs. (13) and (14)).

However, further we take into account that the filament of conduction electrons is not free; the electrons move inside the wire, lying along the axis *x* of K_Q. In addition, we take into account that the absolute contraction of moving bodies, in contrast to SRT, is a real effect, which causes their mechanical deformations. This means that such a deformation induces real mechanical stresses, which influence the character of the deformation itself. In particular, for the considered problem, where the conduction electrons move inside the wire, their filament tends to rotate through the angle *g*, causing a reactive force on behalf of the ion lattice of the conductor. This reactive force prevents a real spatial turning of the electron's filament, maintaining its parallelism to the axis *x*.

Physically this result is quite natural and the only possibility. Thus, due to such a reactive force of positive ions, we have to set up the dash (conduction electron) line in Fig. 8 to be parallel to the full (positive ions) line. In another words, we rotate the dash line through the angle γ in the clockwise direction. The same rotation should be implemented for the vector of electric field $\vec{E}$. As a result, we obtain Fig. 9, where both full and dash lines are parallel to each other, and the vector $\vec{E}$ makes an angle 2*g* with the axis *y*. Since $2\gamma=\alpha$ (see, Eqs.

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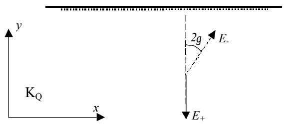

Fig. 9. In real conducting wire the filament of conduction electrons (dash line) and positive ion skeleton (full line) are parallel to each other, and the vector $\vec{E}$ is rotated through the angle 2γ with respect to the axis *y*.

(13) and (14)), the projection of $\vec{E}$ on the axis x is just equal to the value required by the field transformation (7).

Thus, within CETs (Lorentz ether theory) we understood the appearance of an electric field along the axis x in the rest frame of particle Q for the problem in Fig. 4. In our consideration we assumed that the frame K_Q was absolute. One can show that this assumption is not important; the same value of E_x to the adopted accuracy of calculations can be derived under any arbitrary constant absolute velocity of the frame K_Q.

The obtained physical explanation of the field transformation (7) for the problem considered is not so trivial. However, it exists – in contrast to SRT, for which the results are quite contradictory. One should stress that an essence of our explanation was based on two important conclusions of CETs: 1 – Nature always "operates" with the absolute velocities of the frames involved, it "does not know" a relative velocity between two arbitrary inertial frames; 2 – an absolute contraction of moving bodies is a real effect, causing deformations of bodies and the appearance of deformational forces (stresses). (A theory of forces in solid bodies, resulting from the absolute contraction effect, will be analysed in details in a separate paper to be devoted to mechanics of continuums. Hereinafter we use some results of this theory, which seem to be obvious at qualitative level).

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Fig. 10. Ring with the current *I* and charged particle *Q* initially rest in the laboratory. Then the ring begins to spin around the axis *z* at some constant angular frequency *w*. What is the force acting on the particle?

The latter conclusion seems important to resolve a contradiction between the law of transformation of charge density and law of conservation of total charge, in the problem considered in the next Section.

4. Transformation between inertial and rotating frames and the charge conservation law

In this section we will analyse a problem, presented in Ref. [7]. Let there be a superconducting ring with the circulating current *I*, resting in the laboratory frame K (Fig. 10). Let a probe charged particle *Q* also rest in K at some distance *r*>*R* from the axis of the ring (*R* is the radius of the ring). The ring is electrically neutral, and the force acting on the resting charged particle is equal to zero. Then the ring begins to spin at a constant angular velocity *w*. One requires to find the force, acting on the particle.

Solving this problem, we meet a serious contradiction. On the one hand, according to transformation of the four-vector of current density ($\{cr/\sqrt{-g}\,, \vec{j}/\sqrt{-g}\}$, g=det**g**) from an inertial to a rotating frame, the rotating ring acquires a non-zero charge density, homogeneously distributed over its perimeter [8, 9]

$$r_{-} = \frac{wRj}{\sqrt{1-w^2R^2/c^2}}, \tag{19}$$

where $j = I/S$, S being the cross-section of the ring's wire. This result can be understood in another way, if we divide the ring into small straight segments. In each such segment the direction of velocity of conduction electrons, constituting the current *I*, coincides with the direction of linear velocity wR. As a result, a skeleton of ions in each straight segment moves at the constant velocity wR along its axis, while the conduction electrons move at the constant velocity $u' = \dfrac{u + wR}{1 + uwR/c^2}$ along the axis. (Here u is the flow velocity of conduction electrons, constituting the current *I*). This difference of velocities leads to the difference in scale contraction effect for the lattice of positive ions and filament of conduction electrons. Exactly the same situation was analysed earlier in Fig. 1, and it was shown that such an effect causes the appearance of non-vanishing charge density for the straight segment. This implies the appearance of homogeneously distributed charge density over the perimeter of the rotating ring, which is determined by Eq. (19). Hence, the rotating ring is no longer electrically neutral, and it should create an electric field *E* in the radial direction, causing an attraction of the charge *Q*.

On the other hand, the ring is not connected with any sources of charge, it represents a closed system. Hence, the appearance of non-vanishing homogeneously distributed net charge over its perimeter contradicts the law of conservation of charge. This circumstance allowed the authors of Ref. [7] to suppose a possible violation of this law. However, it is rather difficult to accept such a proposition. It seems physically more reasonable to assume a violation of the law of transformation of the four-vector of current density due to the appearance of real stresses in the rotating ring, caused by the absolute deformation of moving bodies.

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Indeed, the filament of conduction electrons rotates not in free space, but inside the ion skeleton. Hence, any absolute contraction of this filament induces the reactive forces on behalf of lattice of positive ions. In the case under consideration (rotation of ring with the current *I*) these reactive forces keep the filament non-deformed, so that the total charge density of the ring remains equal to zero. Any other situation is forbidden by the charge conservation law. As a result, no force acts on the charged particle *Q* under rotation of the ring.

The considered problem indeed is very interesting, because it directly shows an invalidity of the transformation of the four-vector of current density, applied as a mathematical law. In real physical situations it is necessary to take into account another effects (in our case the absolute scale contraction and the appearance of reactive forces in the conductor lattice), in order to obtain a true resolution of the problem. One should notice that the failure of formal mathematics of classical EM theory to describe real physical situations was also revealed under analysis of the Faraday induction law in Ref. [4].

Finally, we notice that for a resting ring and rotating charged particle about the axis z at the angular frequency -*w*, the particle experiences an action of the Lorentz force in the radial direction $QwrB(r)$, where $B(r)$ is the value of magnetic field, created by the current I at the location of the particle. On the other hand, we found above that for rotating ring the force was equal to zero. These results indicate a violation of relativity of rotational motion, as revealed in the Barnett experiment [9, 10].

5. Conclusions

Thus, our analysis of physical problems, dealing with the transformation of EM fields between different reference frames allows one to conclude:

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- under single Lorentz transformations, or under successive Lorentz transformations with collinear velocities, special relativity is successful in explaining the physical origin of the electric and magnetic fields, obtained via corresponding field transformations for different inertial observers. This conclusion is also true for any covariant ether theory. The mathematical basis for this result is the commutativity of space-time and field transformations for collinear relative velocities;
- under successive space-time transformations with non-collinear relative velocities, special relativity fails to explain the origin of the electric and magnetic fields predicted for different inertial observers. In another words, we cannot find a reasonable relationship between the EM fields and their sources. This can be done on the basis of space-time transformations in covariant ether theories, implying the absolute contraction of moving scale and other effects of absolute motion;
- our conception concerning the absolute contraction of moving bodies as being a real deformation, accompanied by real deformational forces (stresses), is one way to resolve a relativistic contradiction between the current density transformation and the law of conservation of charge.

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