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Special Relativity and Quantum Mechanics

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Abstract: It is shown that using the properties of pairs of virtual particles created in the physical vacuum by quantum entities and in the framework of the model of three-dimensional space and independent time it is possible to describe the physical phenomena which are claimed now to be explained only by special relativity: the mass-energy relationship; the transverse Doppler effect for light; the spin-orbit interaction of electrons with the nucleus in an atom; magnetism; the change in the size of a system of electric charges set in motion, the system being in equilibrium under the action of electrostatic forces only. It is also shown that the properties of virtual particles created by quantum entities in the physical vacuum enable one to explain the phenomenon which is inconsistent with the special relativity postulates, that is, quantum correlations of quantum entities.

Keywords: special relativity, pair of virtual particles, speed of light, quantum correlations.

Introduction

Special relativity (SR) made it possible to explain a number of phenomena that had had no explanation in physics; for example, the phenomena categorized as "the optics of moving bodies" (the Michelson-Morley experiment, the Fizeau experiment, and others); the mass-energy relationship; the transverse Doppler effect for light; the Coulomb spin-orbit interaction of atomic electrons and the nucleus; the creation of magnetic field by a moving electric charge; the change in the size of a system of electric charges set in motion (which was studied by H. Lorentz), the system being in equilibrium under the action of electrostatic forces only [1]-[2].

However, SR as any other physical model deals with certain abstractions rather than real entities and the area of its application is restricted. The key restriction is that both postulates which constitute the basis of SR hold only for inertial frames of reference [3]. The first postulate (the principle of relativity) states: there are infinite number of systems of reference (*inertial systems*) moving uniformly and rectilinearly with respect to each other, in which all physical laws assume their simplest form (originally derived for absolute space or the stationary ether). The second postulate (the principle of the constancy of the velocity of light) states: in all *inertial systems* the velocity of light has the same value when measured with length–measures and clocks of the same kind.

SR cannot be applied to such a phenomenon as the birth and annihilation of particles, i.e. the transformation of matter into radiation and vice versa. Besides, the theory is inconsistent with such a phenomenon as quantum correlations of quantum entities, which are performed at "superluminal" speeds [4]. In [5]-[6] it is shown that the physical process responsible for quantum correlations (spin supercurrent in the physical vacuum) is *an inertia free process* and thus has nothing to do with the postulates of SR.

In the present paper it is shown that both the above mentioned phenomena which cannot be explained on the basis of SR and the phenomena which are explained on the basis of SR can be explained using quantum mechanics formalism with due account for the properties of virtual particles and the Galilean law of addition of velocities (in the framework of the model of 3-dimensional space and independent time).

Any quantum entity in the region whose size is of the order of magnitude of the wavelength of the quantum entity creates a pair of oppositely charged virtual particles having spin and mass [7]. A pair of virtual particles may convert into a pair of real particles if the energy of the pair of virtual particles becomes equal to or exceeds energy $2m_0c^2$, where m_0 is the mass of the real particle produced and c is the speed of light. And conversely, pairs of oppositely charged real particles may convert into photons that form pairs of virtual particles in the physical vacuum. In an interaction of quantum entities it is necessary to take into account as well the interaction of virtual particles created by the entities. The concept of virtual particles applies to the description of a number of physical effects: the spontaneous emission of photons, the Casimir effect, the quantum fluctuations in vacuum, the polarization of vacuum in electric fields, the Lamb shift and others.

It is shown in this paper that the concept of virtual particles may be used for describing the following effects: the mass-energy relationship, the Doppler effect for light (both longitudinal and transverse), the spin-orbit interaction of electrons with the nucleus in an atom, the change in the size of a system of electric charges set in motion (the system being in equilibrium under the action of electrostatic forces only), magnetic phenomena, the equality of speed of light to the fundamental constant c in any inertial frame of reference. The concept of virtual particles may be used also for describing the phenomenon that has no explanation in SR, i.e. quantum correlations.

A. Mass-Energy Relationship

The famous relationship between energy U and mass m, $U = mc^2$, was derived by Einstein, who analyzed the pressure of light on matter, energy U being the energy of photon [1]. It is shown in this Section that one can obtain a similar relation between energy and mass while analyzing the characteristics of the pair of oppositely charged virtual particles created by the photon in the physical vacuum: energy U_v, mass m_v, spin S_v. The pair of virtual particles may convert into a pair of real particles with the total spin equal to $\hbar$ if the energy of photon, U_{ph}, becomes equal to or exceeds energy $2m_0c^2$, where m_0 is the mass of the real particle produced and c is the speed of light. Therefore, the energy transformation $U_{ph} \to U_v \to 2m_0c^2$ takes place without dissipation and it may be assumed that

$$U_v = U_{ph} \qquad (1)$$

and besides:

$$S_v = \hbar \,. \qquad (2)$$

The spin of virtual particles has the same properties as those of the real particle spin. Hence it follows that the spin of a pair of virtual particles, S_v, has no definite direction, and by the magnitude of spin the magnitude of its projection onto a preferential direction is meant; this can be interpreted as a precession of the spin about the preferential direction. The precession is characterized by precession angle (phase) α, frequency ω_v, angle of deflection θ and precession energy W_S (see Fig. 1).

As follows from the experiments with spin supercurrent in superfluid ^{3}He-B, the transfer of spin is a dissipation free process [8]-[10]. Therefore, it is reasonable to suggest that in determining the energy associated with spin of a pair of virtual particles, only the energy of precession of spin, W_S, should be taken into account.

The quantity W_S is a function of $\sin\theta$, and its maximum value is $W_S = S_v\omega_v$ at $\theta = \pi/2$ [11]. If to assume that for the photon $\theta = \pi/2$, then with due account of Eq. (2) we have:

$$U_v = W_S = \hbar\omega_v \,. \qquad (3)$$

From Eqs. (1) and (3) and the definition of energy of photon:

$$U_{ph} = \hbar\omega_{ph} \,, \qquad (4)$$

where ω_{ph} is the photon frequency, it follows:

$$\omega_v = \omega_{ph} \,. \qquad (5)$$

Equation (5) may be interpreted in the following way: the precession frequency of the pair of virtual particles created by a photon in the physical vacuum is equal to the frequency of the photon.

The precession of spin of pair of virtual particles means also the circumferential motion of the virtual particle mass associated with the spin. Figure 1 shows the characteristics of a virtual particles pair: $\mathbf{S}_v$ is spin; m_v is mass; r_v is the distance between the mass and the axis aligned with the precession frequency $\boldsymbol{\omega}_v$ under the assumption that the mass is point-like; $\boldsymbol{\upsilon}_m$ is the circumferential velocity of mass; **c** is the photon velocity.

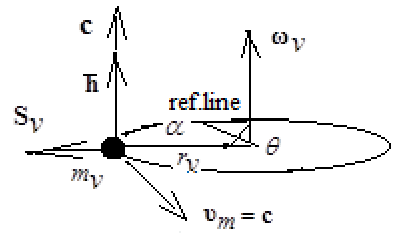

Figure 1. The characteristics of the virtual particles pair created by a photon: $\boldsymbol{\omega}_v$ is the spin precession frequency; $\mathbf{S}_v$ is the total spin; r_v is the distance between the mass and the axis aligned with the $\boldsymbol{\omega}_v$; $\boldsymbol{\upsilon}_m$ is the circumferential velocity of mass m_v; c is the photon velocity; $\hbar$ is the angular momentum of mass m_v; θ is the angle of deflection; α is the precession angle (phase); ref.line is the reference line.

The energy associated with the mass of the virtual particles pair contains two terms, associated respectively with the two types of motion of mass: translational motion with speed c and circular one with velocity $\boldsymbol{\upsilon}_m$. The first term is the kinetic energy, W_m^k, of translational motion of the center of mass, in which all the mass is assumed to be contained:

$$W_m^k = m_v c^2 / 2 \,. \qquad (6)$$

The second term W_m^ω is defined as [11]: $W_m^\omega = J_m\omega_v^2/2$, where J_m is the moment of inertia of mass m_v. The quantity $J_m\omega_v$ determines the angular momentum of mass m_v, and it was established experimentally [12] that for a photon

$$J_m\omega_v = \hbar \,. \qquad (7)$$

Then energy will be determined as

$$W_m^\omega = \hbar\omega_v / 2 \,. \qquad (8)$$

Since the energy of a pair of virtual particles can be expressed both in terms of the spin precession frequency and the energy of mass, we have $W_S = W_m^\omega + W_m^k$. Then using Eqs. (3), (6) and (8), we obtain:

$$U_v = m_v c^2 / 2 + \hbar\omega_v / 2 \,. \qquad (9)$$

From Eqs. (3) and (9) we obtain the equation linking the mass of virtual particle pair and the energy of the pair:

$$m_v = U_v / c^2 \,. \qquad (10)$$

From Eqs. (1), (4) and (10) it follows that $m_v = \hbar\omega_{ph}/c^2$. The latter equation is similar to the equation determining the so-called kinetic mass of photon, $m_{ph} = \hbar\omega_{ph} / c^2$. Using the latter equation and also Eqs. (1), (4), (5) and (10), the Eq. (9) can be written in terms of the characteristics of photon in the following way:

$$U_{ph} = m_{ph}c^2 / 2 + \hbar\omega_{ph} / 2 . \qquad (11)$$

The moment of inertia, J_m, associated with mass m_v can be expressed through r_v: $J_m = m_v r_v^2$. Taking into account Eqs. (1), (5), (7) and (10), we obtain: $2\pi r_v = 2\pi c / \omega_{ph}$. The right side of this equation is the photon wavelength, λ. In view of the latter equation, speed $\upsilon_m = r_v\omega_v$ can be written as

$$\upsilon_m = c . \qquad (12)$$

The virtual particles in a pair are oppositely charged particles, thus the pair of virtual particles is an electric dipole. Therefore, electric field strength **E** is associated with the mass of the pair of virtual particles. It will be shown in Section C, that inside the dipole $\mathbf{E} \uparrow\uparrow \mathbf{S}_v$. Since for the photon $\mathbf{S}_v \perp \boldsymbol{\omega}_v$ and $\mathbf{E} \perp \mathbf{c}$, the following holds:

$$\boldsymbol{\omega}_v \uparrow\downarrow \mathbf{c} \text{ or } \boldsymbol{\omega}_v \uparrow\uparrow \mathbf{c} . \qquad (13)$$

The mutual orientation of vectors $\boldsymbol{\omega}_v$ and **c** determines the handedness of circular polarization of photon.

Some conclusions.

1) The pair of virtual particles formed by a photon possesses mass $m_v = \hbar\omega_v / c^2$, which is equal to the so-called kinetic mass of photon (see also [13]).

2) Mass m_v possesses angular momentum $\hbar$, aligned with $\boldsymbol{\omega}_v$, and consequently is aligned, according to Eq. (13), with the photon velocity or oppositely to that, which determines the handedness of circular polarization of photon.

3) Spin $S_v = \hbar$ is associated with mass m_v, which determines the gyroscopic properties of the mass (which may account for the light polarization preservation observed in the experiments). Actually, a change in the direction of motion or velocity of mass results in a change of space orientation of spin associated with the mass or a change in the spin precession frequency.

4) A pair of oppositely charged virtual particles is an electric dipole. It will be shown in Section C that the electric dipole moment of this dipole and $\mathbf{S}_v$ are aligned oppositely. Thus mass m_v is associated with electric field strength **E**, such that inside the dipole $\mathbf{E} \uparrow\uparrow \mathbf{S}_v$.

Therefore, three mutually perpendicular vectors, i.e. photon velocity **c**, electric field **E**, and velocity $\boldsymbol{\upsilon}_m$ are associated with mass m_v. These three vectors are similar to the components of light, provided vector $\boldsymbol{\upsilon}_m$ is related to the magnetic field induction [14].

B. The Doppler Effect for Light

In this Section it will be shown that using the formula for the energy associated with the mass of virtual particles pair created by a photon, i.e. Eq. (11), it is possible to describe both the longitudinal and the transverse Doppler effect on the basis of the Galilean addition of velocities. It should be noted that the transverse Doppler effect is taken now to be described only by the formalism of SR [1].

Consider an inertial frame of reference fixed relative to the detector, where the source of light is moving at velocity $\boldsymbol{\upsilon}_0$. The source of light is assumed to be at rest with respect to the Earth, the speed of light relative to the source is equal to *c*. It is experimentally established (for example, in the photoelectric effect) that the absorption of light occurs in quanta of energy $\hbar\omega_d$, where ω_d is the frequency of the light being detected. If the mass of the detector as well as the mass of the source are great, both the motion of the source due to recoil in the emission of photon and the motion of the detector due to the pressure of light can be neglected. Then in the interaction of the photon and the detector all the energy U_{ph} of the photon in the inertial frame is equal to the detected energy $\hbar\omega_d$. Using Eq. (11) and taking into account velocity $\boldsymbol{\upsilon}_0$ we have:

$$\hbar\omega_d = \frac{\hbar\omega_{ph}(\mathbf{c} + \boldsymbol{\upsilon}_0)^2}{2c^2} + \frac{\hbar\omega_{ph}}{2} , \qquad (14)$$

where ω_{ph} is the photon frequency in the frame of the source of photons.

(In [15]-[16] it is shown that Eq. (14) can be derived from the laws of conservation of energy and momentum for the photon and source.)

Let us introduce the vector **w** directed from the source to the detector (Fig. 2):

$$\mathbf{w} = \mathbf{c} + \boldsymbol{\upsilon}_0 . \qquad (15)$$

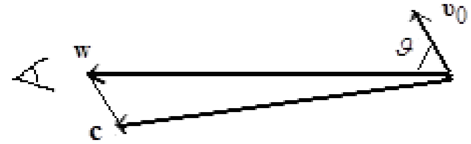

Figure 2. Ray path diagram: c is the light velocity relative to the source; $\boldsymbol{\upsilon}_0$ is the source velocity relative to the detector; w is the resulting light velocity directed from the source to the detector; ϑ is the angle between w and $\boldsymbol{\upsilon}_0$.

Introducing ϑ, the angle between vectors **w** and $\boldsymbol{\upsilon}_0$, denoting $\beta = \upsilon_0 / c$ and using Eq. (15), the Eq. (14) can be expressed as:

$$\hbar\omega_d = \hbar\omega_{ph}\left(1+\frac{(\mathbf{\upsilon}_0\cdot\mathbf{w})}{c^2}-\frac{\upsilon_0^2}{2c^2}\right)$$
$$=\hbar\omega_{ph}\left(1+\frac{w}{c}\beta\cos\vartheta-\frac{1}{2}\beta^2\right) \quad . (16)$$

Quantity w/c can be derived from the following equation: $c^2 = (\mathbf{w}-\mathbf{\upsilon}_0)^2 = w^2+\upsilon_0^2-2w\cdot\upsilon_0\cos\vartheta$.

Dividing both sides of this equation by c^2, we obtain $(w/c)^2-2\beta\cos\vartheta(w/c)-(1-\beta^2)=0$. Taking into account that $w/c>0$ and assuming that $\beta<<1$, we obtain only one solution:

$$w/c=\beta\cos\vartheta+\sqrt{1-\beta^2\sin^2\vartheta}. \quad (17)$$

Substituting the right side of Eq. (17) in Eq. (16), we have:

$$\omega_d=\omega_{ph}\left(1+\beta\cos\vartheta(\beta\cos\vartheta+\sqrt{1-\beta^2\sin^2\vartheta})-\frac{\beta^2}{2}\right).(18)$$

To an accuracy of β^3 the Eq. (18) may be written as:

$$\omega_d=\omega_{ph}[1+\beta\cos\vartheta+\beta^2\cos^2\vartheta-\frac{\beta^2}{2}$$
$$-\frac{\beta^3}{2}\cos\vartheta\left(1-\cos^2\vartheta\right)+o\left(\beta^3\right)] \quad , \quad (19)$$

where $o\left(\beta^3\right)$ are summands of a lower order of magnitude than β^3. Equation (19) coincides accurate to β^2 inclusive (at $\vartheta=\pi/2$ accurate to β^3 inclusive) with the equation describing Doppler's effect in SR [1]:

$$\omega_d=\omega_{ph}\frac{\sqrt{1-\beta^2}}{1-\beta\cos\vartheta}=\omega_{ph}[1+\beta\cos\vartheta+\beta^2\cos^2\vartheta$$
$$-\frac{\beta^2}{2}-\frac{\beta^3}{2}\cos\vartheta+\beta^3\cos^3\vartheta+o(\beta^3)] \quad .$$

Let us consider the special cases. If $\cos\vartheta=0$, the formula describing the transverse Doppler effect follows from Eq. (19): $\omega_d=\omega_{ph}\left(1-\beta^2/2\right)$. If $\cos\vartheta=1$ or $\cos\vartheta=-1$, the formula describing the longitudinal Doppler effect follows from Eq. (19): $\omega_d=\omega_{ph}\left(1+\beta+\beta^2/2\right)$ or $\omega_d=\omega_{ph}\left(1-\beta+\beta^2/2\right)$ respectively.

Note that in the Eq. (14) for the energy of photon the velocity of photon relative to the detector is assumed to be $\mathbf{c}+\mathbf{\upsilon}_0$. However, the results of experiments show that the speed of light with respect to the detector is equal to fundamental constant c irrespective of the motion of detector. Since Eq. (14) describes adequately the Doppler effect, both longitudinal and transverse, one may suppose that the speed of light, while being detected, is becoming equal to the fundamental constant c, the energy being transformed according to Eq. (14).

In the case discussed above, the source of light is at rest relative to the Earth. However, it can be shown that Eq. (19) will not change if the source does move with respect to the Earth and the photon's speed is made equal to the fundamental constant c with respect to the Earth, with the energy being transformed according to Eq. (14).

Therefore, one can reasonably suggest that the speed of light may become equal to the fundamental constant c in inertial frames of reference, with the energy being transformed according to Eq. (14).

C. Spin-Orbit Interaction

The electric properties of virtual particles are the same as those of real particles. Consequently, a pair of oppositely charged virtual particles is an electric dipole whose electric properties are the same as those of the electric dipole produced by oppositely charged real particles, i.e. it possesses an electric dipole moment (see also [6] and [15]). Let us determine the value of this moment, d_v. The electric dipole is associated with spin $\mathbf{S}_v$ of the pair of virtual particles, and the precession of the spin with frequency ω_v means the precession of electric dipole moment, d_v, see Fig. 3.

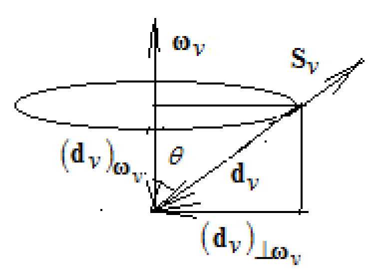

Figure 3. Diagram of precession of electric dipole moment $\mathbf{d}_v$ with precession frequency $\boldsymbol{\omega}_v$; $\mathbf{S}_v$ is spin of virtual particles pair; θ is the angle of deflection; $(\mathbf{d}_v)_{\boldsymbol{\omega}_v}$ is the projection of $\mathbf{d}_v$ onto $\boldsymbol{\omega}_v$; $(\mathbf{d}_v)_{\perp\boldsymbol{\omega}_v}$ is the projection of $\mathbf{d}_v$ onto the line normal to $\boldsymbol{\omega}_v$.

The projections of $\mathbf{d}_v$ onto $\boldsymbol{\omega}_v$ and onto the line normal to $\boldsymbol{\omega}_v$, that is $(\mathbf{d}_v)_{\boldsymbol{\omega}_v}$ and $(\mathbf{d}_v)_{\perp\boldsymbol{\omega}_v}$ respectively, are expressed as:

$$\left|(\mathbf{d}_v)_{\boldsymbol{\omega}_v}\right| = d_v \cos\theta = d_v \sqrt{1-\sin^2\theta}\,, \qquad (20)$$

$$\left|(\mathbf{d}_v)_{\perp\boldsymbol{\omega}_v}\right| = d_v \sin\theta\,. \qquad (21)$$

According to [11], the energy of precession, W_S, of the spin of pair of virtual particles will depend on angle θ and varies from $W_S = 0$ at $\theta = 0$ to $W_S = S_v\omega_v$ at $\theta = \pi/2$. In Section 2 it was shown that if a pair of virtual particles is created by a photon (the speed of the pair is *c*), then $\theta = \pi/2$. If a quantum entity has zero speed, $W_S = 0$, which corresponds to $\theta = 0$. Thus when speed u of the entity that creates a pair of virtual particles varies from 0 to *c*, angle θ varies from 0 to $\pi/2$. Therefore, at least for $u << c$ it may be assumed that

$$\sin\theta = u/c = \beta\,. \qquad (22)$$

Using Eq. (22) in Eq. (20), we obtain:

$$\left|(\mathbf{d}_v)_{\boldsymbol{\omega}_v}\right| = d_v\sqrt{1-\beta^2}\,. \qquad (23)$$

According to Eq. (13), the direction of $\boldsymbol{\omega}_v$ is determined by the direction of velocity of the quantum entity that creates the virtual particles pair, that is, by the direction of **u**. So the following holds:

$$\left|(\mathbf{d}_v)_{\boldsymbol{\omega}_v}\right| = \left|(\mathbf{d}_v)_{\mathbf{u}}\right|. \qquad (24)$$

If the quantum entity is an electric charge, then the electric field created by the entity will act on the direction of $(\mathbf{d}_v)_{\boldsymbol{\omega}_v}$: for the electron $(\mathbf{d}_v)_{\mathbf{u}} \uparrow\uparrow \mathbf{u}$, for the positron $(\mathbf{d}_v)_{\mathbf{u}} \uparrow\downarrow \mathbf{u}$. In the general case:

$$(\mathbf{d}_v)_{\mathbf{u}} \uparrow\downarrow \mathbf{I}\,, \qquad (25)$$

where **I** is the electric current created by the moving charged quantum entity. Taking into account Eq. (25) and assuming that $\mathbf{d}_v \uparrow\downarrow \mathbf{S}_v$ (see Fig. 3), we can write:

$$\boldsymbol{\omega}_v \uparrow\uparrow \mathbf{I}\,. \qquad (26)$$

In the electric field **E** a moment **M** will act on the electric dipole formed by the pair of virtual particles:

$$\mathbf{M} = \mathbf{d}_v \times \mathbf{E}\,. \qquad (27)$$

Let us consider the spin-orbit interaction energy for the electron in a hydrogen atom and to this end let us specify the value d_v for the electron (denoting the moment as d_v^e) [14]:

$$d_v^e = q_v L\,, \qquad (28)$$

where q_v is the charge of a virtual particle, *L* is the distance between the virtual particles in the pair. We assume that the specific charge of the virtual particle produced by an electron is equal to the specific electron charge:

$$e/m_e = 2q_v/m_v\,, \qquad (29)$$

where *e* and m_e are the electric charge and mass of electron, respectively; factor 2 in the right-hand side of the equation is due to the fact that the mass of only one virtual particle of the pair must be used in the equation. (The results of Kaufmann's experiments on electric and magnetic deflection of beta-rays suggest that the mass of electron is of electromagnetic nature [17].) A pair of virtual particles is created by a quantum entity in the region whose size is of the same order of magnitude as the wavelength of the quantum entity, $\lambdabar$. Therefore, we may assume that $L = \lambdabar$. Using this equality and Eq. (29) in Eq. (28), we have:

$$d_v^e = \lambdabar e m_v/(2m_e)\,. \qquad (30)$$

We assume that, as in the case of photon (see Eq. (1)), the energy U_v of the pair of virtual particles created by an electron is equal to the energy of electron. If the energy of electron is equal to its kinetic energy, $m_e u^2/2$, then using the mass-energy relationship (10) for determining m_v, also the expression for wavelength $\lambdabar = \hbar/(m_e u)$ and the expression for Bohr's magneton $\mu_B = e\hbar/(2m_e c)$, the Eq. (30) can be written as:

$$d_v^e = \frac{\mu_B}{c}\frac{u}{2}\,. \qquad (31)$$

The projection of precessing vector $\mathbf{d}_v^e$ onto the velocity **u** of electron, $(\mathbf{d}_v^e)_{\mathbf{u}}$, with due account of Eqs. (20), (22), (24) and (25), can be expressed as

$$(\mathbf{d}_v^e)_{\mathbf{u}} = \frac{\mu_B\sqrt{1-u^2/c^2}}{2c}\mathbf{u}\,. \qquad (32)$$

For the electron in a hydrogen atom $u^2/c^2 \sim 10^{-4}$, thus the factor $\sqrt{1-u^2/c^2}$ in Eq. (32) can be taken to be equal to 1; then moment **M** acting upon the electron in a hydrogen atom may be expressed, according to Eq. (27), as follows: $\mathbf{M} = \frac{\mu_B}{2c}(\mathbf{u}\times\mathbf{E})$. The expression in the right-hand side is the same as that for the spin-orbit interaction energy for the electron in a hydrogen atom: $U_{s-o} = \mathbf{n}\frac{\mu_B}{2c}(\mathbf{u}\times\mathbf{E})$ (the unit vector **n** is aligned with electron's magnetic moment which is equal to μ_B) if $\mathbf{n} \uparrow\uparrow (\mathbf{u}\times\mathbf{E})$. In this case **E** is the electric field strength produced by the nucleus at the location of the electron. The equation for U_{s-o} was derived by L. Thomas with due account of general requirements of relativistic invariance [18].

Note. We shall derive electric dipole moment for the pair of virtual particles created by a photon, d_v^{ph}. To determine d_v^{ph}, Eqs. (10), (28) and (29) are used resulting in: $d_v^{ph} = e\hbar\omega_{ph}\lambdabar_{ph} / \left(2m_e c^2\right)$. Taking into account that for the photon $\omega_{ph}\lambdabar_{ph} = c$ and using the expression for Bohr's magneton: $\mu_B = e\hbar / \left(2m_e c\right)$, we obtain: $d_v^{ph} = \mu_B$.

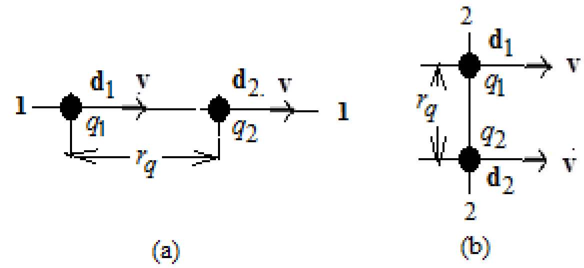

Figure 4. Variants (a) and (b) for alignment of velocities v (aligned with the straight line 1-1 or normal to straight line 2-2) of two respective charges q_1 and q_2 having electric dipole moment $\mathbf{d}_1$ and $\mathbf{d}_2$ respectively; r_q is the distance between the charges.

D. The Change in the Size of a System of Electric Charges Set in Motion, the System Being in Equilibrium Under the Action of Electrostatic Forces Only

It was H. Lorentz who noticed that a system of electric charges, being in equilibrium only under the action of electrostatic forces, when set in motion contracts in the direction of the motion. [1] (Note that the hypothesis of length contraction in the direction of motion was first advanced by Fitzgerald in 1832).

In this Section it will be shown that it is possible to offer a physical explanation to this phenomenon if to take into account the electric dipole moment of virtual particles pair created by a quantum entity in the physical vacuum (see also [6] and [15]).

For simplicity sake we shall consider a system of two electrically charged quantum entities, the system moving at velocity **v**. Let us denote by q_1 and d_1 the magnitudes of the charge and electric dipole moment, respectively, of the first entity and by q_2 and d_2 the respective characteristics of the second entity. The force of interaction between the two entities has two components: the force due to interaction between them as electric dipoles, F_d, and the force due to interaction between them as electric charges, F_q:

$$F_q = \frac{k_q q_1 q_2}{r_q^2}, \qquad (33)$$

where k_q is the coefficient determined by the system of units used in the calculations, r_q is the distance between the charges. Let us consider two types of alignment of velocities of the electric charges q_1 and q_2: along the same straight line (Fig. 4a), and parallel to each other (Fig. 4*b*).

Let us determine the resultant force between the two charges for the case of Figure 4*a*. In this case the force F_d is expressed as [14]:

$$F_d = \frac{6\left(d_1\right)_{\mathbf{v}}\left(d_2\right)_{\mathbf{v}}}{r_q^4}. \qquad (34)$$

Taking into account Eq. (25) at any combination of signs of q_1 and q_2, the forces $\mathbf{F}_q$ and $\mathbf{F}_d$ are directed oppositely, being aligned with the same straight line 1-1. Thus the resultant force F_{11} acting on either of the charges along to velocity **v** will be: $F_{11} = \left|F_q - F_d\right|$. According to Eqs. (23)-(25), (33) and (34), F_{11} will be expressed as

$$F_{11} = \frac{k_q q_1 q_2}{r_q^2}\left|1 - \frac{6 d_1 d_2\left(1-\beta^2\right)}{k_q q_1 q_2 r_q^2}\right|. \qquad (35)$$

Let us determine now the resultant force between the two charges for the variant of their mutual position shown in Fig.4b. In this case F_d is expressed as [14]:

$$F_d = \frac{3\left(d_1\right)_{\mathbf{v}}\left(d_2\right)_{\mathbf{v}}}{r_q^4}. \qquad (36)$$

Taking into account Eq. (25) at any combination of signs of q_1 and q_2, the forces $\mathbf{F}_q$ and $\mathbf{F}_d$ (the latter being determined by Eq. (36)) have the same direction, being aligned with the same straight line 2-2 which is normal to velocity **v**. Thus the resultant force F_{22} acting on the charges normally to velocity **v** will be: $F_{22} = \left|F_q + F_d\right|$. According to Eqs. (23)-(25), (33) and (36), the resultant force F_{22} acting on either of the charges normally to velocity **v** will be:

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$$F_{11} = \frac{k_q q_1 q_2}{r_q^2}\left|1+\frac{3d_1 d_2\left(1-\beta^2\right)}{k_q q_1 q_2 r_q^2}\right|. \qquad (37)$$

Thus the motion of electric charges of any sign results in a decrease of the electric force acting between the charges in the direction of motion, with the reduction factor, according to Eq. (35), of $1-\frac{6d_1d_2}{k_q q_1 q_2 r_q^2}\left(1-\beta^2\right)$ and results in an increase of the force acting in the normal direction, with the amplification factor, according to Eq. (37), of $1+\frac{3d_1d_2}{k_q q_1 q_2 r_q^2}\left(1-\beta^2\right)$. If either of the moving charges is an electron or positron and the energies of the moving charges are equal to their kinetic energies, then, taking into account the expression for the electric dipole moment Eq. (31), and that for β, Eq. (22), the reduction factor is,

$$1-\beta^2\frac{6\mu_B^2}{4k_q r_q^2 e^2}\left(1-\beta^2\right)=1-\beta^2\frac{6\mu_B^2}{4k_q r_q^2 e^2}+\beta^4\frac{6\mu_B^2}{4k_q r_q^2 e^2},$$

and amplification factor is

$$1+\beta^2\frac{3\mu_B^2}{4k_q r_q^2 e^2}\left(1-\beta^2\right)=1+\beta^2\frac{3\mu_B^2}{4k_q r_q^2 e^2}-\beta^4\frac{3\mu_B^2}{4k_q r_q^2 e^2},$$

Thus if to take into account the electric dipole moment of virtual particles pair created by a quantum entity in the physical vacuum, then it is possible to offer a physical explanation to the following experimentally observed phenomenon: the change in the size of a system of electric charges being in equilibrium only under the action of electrostatic forces between the charges when the system is set in motion.

E. Magnetism

Due to the precession of the spin $\mathbf{S}_v$ of the pair of virtual particles, created by a quantum entity, the mass m_v of the pair of virtual particles, associated with the spin, performs circular motion in the plane perpendicular to precession frequency $\boldsymbol{\omega}_v$ (see Fig. 5). Angular momentum $\mathbf{Z}$ is associated with the motion,

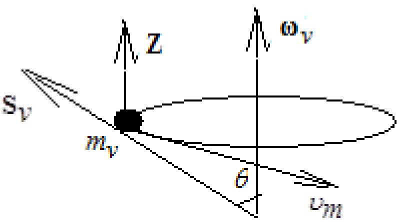

Figure 5. The characteristics of a pair of virtual particles: $\mathbf{S}_v$ is spin of the pair; m_v is the mass of the pair; $\boldsymbol{\omega}_v$ is the precession frequency of the pair; Z is the angular momentum of virtual particles pair possessing mass m_v ; θ is the deflection angle; υ_m is the circumferential velocity of mass m_v .

The circular motion of m_v with angular momentum $\mathbf{Z}$ can be regarded as a vortex motion.

Let us consider an electric current. Since the electric current is a motion of electrically charged quantum entities creating pairs of virtual particles with angular momentum **Z**, then according to Eq. (26) and taking into account that $\mathbf{Z}\uparrow\uparrow\boldsymbol{\omega}_v$, the electric current may be taken to be a vortex line in the physical vacuum. This vortex line can be characterized by circulation $\boldsymbol{\Gamma}$.

It is shown in [11] that there is a complete analogy between the structures of formulas describing the magnetic interactions of current-carrying wires and the structures of formulas describing the interactions of vortices in an ideal incompressible liquid with positive density and negative pressure. We shall derive some equations that establish a relationship between the characteristics of magnetic field and both dynamic and kinematic characteristics of the vortex line in the medium consisting of pairs of virtual particles: (see also [13], [15], and [19]).

Interaction of infinite vortex lines and interaction of two infinite current-carrying wires. The force acting on the unit length of either of the two infinite mutually parallel vortex lines having the same values of circulation $\boldsymbol{\Gamma}$ is $F=\rho\Gamma^2/\left(2\pi r_w\right)$, where r_w is the distance between the vortex lines with circulation Γ, ρ is the density of the medium where the vortex lines interact [11]. The force acting on the unit length of either of the two infinite mutually parallel current-carrying wires is $F=2I^2/\left(r_w c^2\right)$, where I is the current, r_w is here the distance between the current-carrying wires [14]. By equating the above expressions for the forces and taking into account that the forces are attractive if the currents as well as velocity circulations around the vortex lines have the same direction, we obtain:

$$\boldsymbol{\Gamma}=\frac{2\mathbf{I}}{c}\sqrt{\frac{\pi}{\rho}}. \qquad (38)$$

The field of velocities $\mathbf{y}$ *generated by a closed vortex line and the magnetic induction* $\mathbf{B}$ *around a current loop*. The field of velocities $\mathbf{v}$ generated by a closed vortex line having circulation $\boldsymbol{\Gamma}$ along an arbitrary loop enclosing the vortex line is defined as [11]: $\mathbf{y}=\frac{\Gamma}{4\pi}\int_{L'}\frac{d\mathbf{I}\times\mathbf{r}}{r^3}$, where $d\mathbf{l}$ is an infinitesimal vector element of the vortex line, $L^{'}$ is the length of the line, **r** is a radius vector from $d\mathbf{l}$ to the point of observation. Outside the vortex line, $curl\mathbf{y} = 0$. The structure of equation for **y** is the same as the structure of equation for the magnetic induction **B** generated by a loop with current *I*, the length of the loop is $L^{'}$ (the Biot-Savart law) [14]: $\mathbf{B} = \frac{I}{c}\int_{L'} \frac{d\mathbf{I} \times \mathbf{r}}{r^3}$. Having solved simultaneous equations for **B**, **y** and Eq. (38), we obtain an equation linking the magnetic induction **B** and the velocity **y** of the medium:

$$\mathbf{B} = \mathbf{y} \cdot 2\sqrt{\pi\rho}\,. \qquad (39)$$

As it was mentioned above, Equation (39) was derived under the condition that magnetic interactions are like interactions of vortices in an ideal incompressible liquid with positive density and negative pressure. The sign of the pressure depends on the nature of internal stresses in the medium. If the internal stresses are like “omniradial tensions” [11], the pressure will be negative. Such properties might be characteristic of the medium formed by pairs of virtual particles, because at a definite energy the pairs may be decomposed into the constituent particles, the mass of the particles being positive. This is also characteristic of the “cosmic vacuum” [20]. According to the current models of “cosmic vacuum”, 70 percent of all energy of the universe is in the form of so-called dark energy or “quintessence”, which is characterized by the homogeneous distribution of positive density and negative pressure. The “quintessence” does not emit, absorb or reflect light, which is quite explicable if to suppose that light propagates in the “quintessence” as a process.

Conclusion. As follows from this Section, the magnetic interactions may be taken to be interactions of vortices produced by virtual particles created by moving electric charges in the physical vacuum (see also [15] and [21]).

F. The Speed of Light

Since photons form in the physical vacuum pairs of virtual particles having mass, light is a process in a gravitational field. Thus the speed of light is determined by the properties of the gravitational field and may become equal to a definite value with respect to the sources of the field (e.g. entities having mass) in the interaction with these sources (see [13], [15], and [16]). The equalization of the speed of light relative to the entities having nonzero mass is in agreement with the second SR postulate, according to which in any inertial frame of reference the speed of light is equal to the fundamental constant *c*.

> *Note.* A special case of equalization of the speed of light is dealt with in the emission theory by W. Ritz. In 1908, he suggested that the fundamental constant *c* is the speed of light with respect to the source of light in vacuum and that the Galilean addition of velocities holds [22]. The so-called Ritz emission theory is in accord with observation of the aberration of star positions, the Fizeau experiment, the original Michelson−Morley experiment, and most other experiments carried out for determining the “ether wind” [2].

The pair of virtual particles created by a quantum entity with nonzero rest mass differs from the pair of virtual particles created by a photon just in the speed of motion. At the speed of motion equal to the speed of light, the difference vanishes and the motion of quantum entity will be accompanied by emission of radiation. This phenomenon is observed in the experiments with electrons moving at a superluminal speed and is referred to as Vavilov-Cherenkov’s effect [22].

The equalization, that is a change in the speed of light near large masses, means that there will be refraction of light near large masses. Thus the bending of a beam of light near the Sun will be controlled by two factors: the gravitational interaction between the kinetic mass of photon and the mass of the Sun, and the refraction of the beam of light due to equalization of its speed. This agrees with the results of the experiments where the observed light ray bending near the Sun is not exclusively accounted for by the gravitational interaction of the light with the Sun mass [1].

G. Quantum Correlations

According to postulates of quantum mechanics, the virtual particle spin has the same properties as the real particle spin. Hence it follows that spin correlations, such as the equalization of the respective phases of precession and angles of deflection may take place between the spins of pairs of virtual particles (see Fig. 6).

As follows from the experiments with superfluid ^{3}He-B spin, correlations can be effected through spin supercurrents [8]-[10]. In the case where the precession frequencies are aligned with an axis *z*, the spin supercurrent component in the direction of axis z, J_z, is determined as: $J_z = -b_1(\alpha_1 - \alpha_2) - b_2(\theta_1 - \theta_2)$, where b_1 and b_2 are proportionality factors depending on the properties of the medium, α_1 and α_2 are precession angles of interacting pairs of virtual particles, θ_1 and θ_2 are deflection angles of interacting pairs of virtual particles. In Figure 6 are shown the characteristics of two interacting pairs of virtual particles having spin $\mathbf{S}_v$ and precession frequencies $(\boldsymbol{\omega}_v)_1$ and $(\boldsymbol{\omega}_v)_2$.

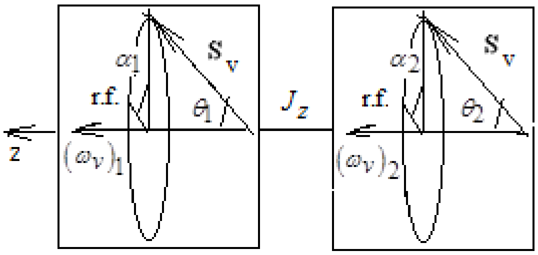

Figure 6. Some characteristics of two interacting pairs of virtual particles: S_v is spin; $(\omega_v)_1$ and $(\omega_v)_2$ are the precession frequencies; θ_1 and θ_2 are the deflection angles; α_1 and α_2 are the precession angles (phases) counted off from the reference line, r.f. are reference lines, J_z is the spin supercurrent component in the direction of axis z.

It is shown in [5]-[6] that the main characteristics of quantum correlations between quantum entities are similar to those of the spin supercurrent emerging between spin structures in superfluid ^{3}He-B [8]-[10]. Thus one may assume that quantum correlations between quantum entities are due to spin supercurrents arising between pairs of virtual particles created by the quantum entities.

Spin supercurrent arises between pairs of virtual particles, but it does not produce the latter. Therefore, spin supercurrent is not accompanied by the birth of a mass and consequently is not a process in the gravitational field. Thus the speed of spin supercurrent may have any value with respect to singularities in the gravitational field and therefore may be greater than the speed of light. In other words, spin supercurrent is an *inertia free process* and thus the postulates of SR do not apply to spin supercurrent, because the postulates are valid for *inertial systems* only.

H. Discussion

As shown in Section C the motion of like charges is accompanied by a formation by these charges of electric dipoles with unidirectionally oriented electric dipole moments (see Eq. (25)). As a result, the electric field of these electric dipoles will form an electric field near the current-carrying wire, the wire being neutral in the absence of the current. Let us define the emerging electric field. To this end, let us consider the projections of electric dipole moment of the moving charge $\mathbf{d}_v$ on the velocity $\mathbf{u}$, $(\mathbf{d}_v)_{\mathbf{u}}$, and on the perpendicular direction, $(\mathbf{d}_v)_{\perp\mathbf{u}}$ (see Fig. 3). Because of the precession of $(\mathbf{d}_v)_{\perp\mathbf{u}}$ about the direction of the velocity of the charge, the average magnitude of projection $(\mathbf{d}_v)_{\perp\mathbf{u}}$ on any direction perpendicular to $\mathbf{u}$ for the period of precession is equal to zero. As concerns $(\mathbf{d}_v)_{\mathbf{u}}$, it is directed, according to Eq. (25), oppositely to the direction of the current. Therefore, the electric current can be taken to be a sequence of electric dipoles oriented oppositely to the direction of the current. According to [14], the total electric field of a sequence of electric dipoles, whose electric dipole moments are unidirectional and of the same magnitude, will be equal in strength to the electric field created by a single dipole.

Conclusion

On the basis of the properties of pairs of virtual particles created by quantum entities in the physical vacuum it is possible, using the Galilean law of addition of velocities (in the framework of the model of 3-dimensional space and independent time), to explain the phenomena that have had explanations only in special relativity:

- the mass-energy relationship;
- the Doppler effect (longitudinal and transverse) for light;
- the spin-orbit interaction of atomic electrons and the nucleus;
- the change in the size of a system of electric charges set in motion, the system being in equilibrium under the action of electrostatic forces only;
- the creation of magnetic field by moving electric charges;
- the equality of speed of light to the fundamental constant *c* in any inertial frame of reference;

and also the phenomenon that has had no explanation in special relativity:

- quantum correlations of quantum entities; the speed of the physical process responsible for quantum correlations, i.e. spin supercurrent, may exceed the speed of light because the process is inertia free and the postulates of special relativity do not apply in this case.

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Biography

Liudmila Borisovna Boldyreva graduated from Moscow Engineering Physics Institute. She defended her PhD thesis on processing results of physical experiments. For about 30 years she has been studying the properties of physical vacuum. The results are published in her book "What does this give to physics: attributing the properties of superfluid ^{3}He-B to physical vacuum?" and in the papers, part of which are referred to in this paper. At present she works as Associate Professor at the State University of Management (Moscow),

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