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The New Approach and Superlight Particle Production

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Abstract

On the basis of the author's work on classical mechanics, action on high-speed particles is examined. A force, applied to a particle, is shown to change along with the particle velocity, while the particle's mass remains the same. The processes in modern particle accelerators within a new action description are examined. The principle of particle acceleration that exceeds the velocity of light is given. The necessary conditions for its realization are calculated and considered to be possible in contemporary state-of-the-art accelerators.

Key words: constant mass, D'Alembert equation, electrical and magnetic forces, superlight velocity, superlight acceleration conditions for superlight realization

Some works critical of the theory of relativity have recently been published.[1,2] In the early 1970s the present author also questioned this theory.[3] I subsequently worked out non-relativistic calculations of high-speed particle interactions.[4] In the present paper, written in 1973, the method of obtaining velocity beyond the speed of light, "superlight velocity," is described.

1. INTRODUCTION

In the recent literature there are papers on particles with superlight velocities. These particles are called tachyons. Nobody has discovered tachyons yet; their existence has been assumed only.

In the nineteenth century there was little interest in the existence of particles that could travel faster than the velocity of light — "superlight particles." At that time there were no velocity limitations in physics. The gravitational action propagation velocity was thought to exceed the velocity of light. And with the help of then known reactive action, it would be possible to achieve superlight velocity. But now superlight particles seem puzzling.

It is well known that the theory of relativity is applied in science and technology. Elementary particle accelerators are constructed on its basis, and the theory is used for the calculation of nuclear power.

The theory of relativity is based, in general, upon the supposition that mass, particles, or any action or wave cannot exceed the velocity of light.

Hence either the theory of relativity is taken into account and the existence of tachyons is impossible, or the existence of tachyons is believable and the theory of relativity is incorrect.

Scientists studying tachyons[5-7] do not follow either of the above alternatives. They try to coordinate the theory of relativity with the existence of tachyons. For example, the title of Ref. 5 clearly expresses this idea. This idea provokes new suppositions, including assumptions about imaginary mass. This is the theory of relativity conception extension. For instance, Ref. 7 reports on Lorentz transformation propagation on inertial systems where the relative velocity exceeds the velocity of light. The generalized causality principle is introduced, according to which the statement that a cause leads to an effect is a frequent case. This is the real part of the generalized principle, while the imaginary part assumes that an effect precedes a cause. Introducing the generalized causality principle tends to get rid of the contradictions between the superlight motions and the theory of relativity cause-and-effect relationships. Reference 8 illustrates such a tendency.

The present paper examines superlight particles in another light. We shall not try to connect superlight motions with an assumption or hypothesis, since an assumption is not a fact yet. The assumption may be believable when the natural explanation based on it is satisfactory, but it must be abandoned with any profitable occasion, because the explanation based upon the assumption is imaginary. The real explanation must be based on the facts.

We consider that the theory of relativity assumption, that motion faster than light is impossible, is incorrect.

This limitation was introduced so that the description mode of the interaction of moving charged particles could be made. We shall introduce a new approach of those action descriptions and demonstrate its difference from the current mode. With the help of the new method, we can calculate the conditions for superlight motions.

2. THE DESCRIPTION OF THE INTERACTION OF MOTIONLESS CHARGED BODIES; MEANING OF THE TERMS "FORCE" AND "ACCELERATION"

We shall examine the motions of elementary charged particles. Every particle is characterized by the electrical charge magnitude q_1 and mass m_1. During the action on the charged object with the charge q_2, with its own dimensions significantly smaller than the distance **R** to the particle, the force per particle is expressed by

Coulomb's law:

$$\mathbf{F} = \frac{q_1 q_2 \mathbf{R}}{\varepsilon R^3}. \tag{1}$$

If the dimensions of the charged object cannot be ignored, it is necessary to calculate the sum of forces from all its elements, that is, it must be integrated. We consider a charged object to be a charged particle, a charged body, or charged electrodes of, for example, charged capacitor plates.

The acceleration of a particle under the object action is expressed by Newton's second law:

$$\mathbf{w} = \mathbf{F}/m_1. \tag{2}$$

Thus the action on the particle causes its acceleration. It embodies the change in particle motion under the action. The particle acceleration and trajectory changes and curvilinear motion of the particles are characterized by its acceleration. Therefore, it is a direct expression of action on the particle. If there is no velocity change, that is, no particle acceleration, there is no action on it, and vice versa, if there is particle acceleration, there is an action on it. Note that under the simultaneous action of one object and counteraction of another one on the body, the latter may be without acceleration and even at rest. But the acceleration will occur immediately after the counteraction is eliminated. Due to this acceleration motion we conclude that the body was affected by the mutually opposite actions.

The term "force" is an intermediate characteristic that does not occur during particle motion. Force is included in the method of action description. Some methods of action are known in physics without force, for example, due to energy.

If the acceleration magnitude fully characterizes the action on the particle, the force magnitude, at a certain approach, cannot explain the action magnitude. For example, if the mass is assumed to change as the velocity changes, the same force magnitude will correspond to different accelerations at different velocities. And even motion that is not accelerating, with mass m tending to infinity, can correspond to nonzero force, that is, although there is no particle acceleration, the force is applied to the particle. This example explains the situation with the mass and force position in the theory of relativity.

Thus the action on the particle is actually expressed or exhibited during particle acceleration. The action description may be expressed by different notions including the force.

3. THE CURRENT DESCRIPTION OF THE ACTION ON THE MOVING CHARGED PARTICLE CONTRADICTS THE OBSERVED PHENOMENA

Let us see how the notion of mass depending on velocity was introduced into the theory of relativity. At the end of the nineteenth century and beginning of the twentieth century, scientists performed experiments on the acceleration of a charged particle and measured its velocity. It was concluded that particle velocity after acceleration was lower than the magnitude derived using Coulomb's law (1). For instance, during particle acceleration, between the charged plates the particle velocity must be equal to $(2qU/m)^{1/2}$, where q and m are the particle's charge and mass, and U is the potential difference between the plates. The actual particle velocity is smaller than this magnitude. The difference between the velocities increases as the velocity of the particle increases. From the experiments it was determined that even with the large charge affecting the object (or the potential difference passed by the particle) the particle velocity will not exceed the electromagnetic wave propagation velocity, $c_1 = c/(\mu\varepsilon)^{1/2}$.

From the natural point of view this fact was explained as follows: the electrical action with finite velocity c_1 can accelerate the particle only until its velocity does not exceed this electrical action propagation velocity. The discrepancy between the experimental data and Coulomb's law (1) was explained by various hypotheses. For example, Lorentz assumed that an electron obtains the electromagnetic mass during its motions. According to this hypothesis, as velocity v increases, mass increases and particle acceleration decreases, although the force calculated by Coulomb's law is still in action. Lorentz offered this formula to determine the change in mass: $m = m_0/(1 - \beta^2)^{1/2}$, where $\beta = v/c$.

In the theory of relativity created later, Lorentz' hypothesis was modified. It was accepted that as velocity increases, mass increases — like the energy does — according to Lorentz' law. It was assumed that mass is not only electromagnetic, but it increases as the velocity increases under any action. Therefore, in any case, once a particle achieves the velocity of light, it no longer accelerates. According to this method, as long as the mass achieving the velocity of light tends to infinity, this velocity is perceived as a limit in the theory of relativity.

But let us detour from the hypothesis for a moment and point out the fact: a charged particle gets less acceleration from a charged object, the closer its velocity is to c_1. Hence the action on the particle decreases as the velocity increases. The correct action description must correspond to this fact. And if the action is described by the force, the force on the particle must decrease as the velocity of the particle increases and tend to zero achieving the velocity c_1. The description of the action on the charged particle in Coulomb's law form (1) does not correspond to this fact. Hence this description is incorrect.

On the other hand, can Coulomb's law be considered as description of the action on moving charged particles? Since Coulomb's law measures the forces of interaction between motionless charged bodies, its application to motionless charged particles gives increased error the higher the velocity of the particles. Even this given the fact that with help of Coulomb's law it is possible to calculate the motionless body interactions and — with a slight error — the slow moving body interactions. And for the description of the action on high-velocity charged particles, the new force expression is necessary. This time, the force must depend on velocity and at $v \to c_1$ must tend to zero.

4. THE NEW DESCRIPTION BASED ON FACTS

Coulomb's law was formulated by measuring the force between two charged objects. To be more exact, the electrical charge unit was chosen due to the force magnitude. The force between electrically charged bodies was measured by the spring deformation or comparison to the weight force, but all measurements were made for the interactions between motionless bodies relative to each other.

The force on the motionless body might be measured during one body motion relative to another. Knowing the bodies' charges, the distance between them and moving body velocities, at the measurement moment, the force dependence on these parameters can be calculated. But since such measurements were not made, we shall choose the following way to determine the expression of the action force on the moving charged particle.

At the end of the previous century Röntgen, Rowland, and Eichenwald studied the moving charged body action on a magnetic needle. Comparing this action with the wire conductor action on the same magnetic needle, the moving charged body can correspond to a certain current. This current will depend upon the body charge magnitude, its velocity, and body form or charge distribution, that is, for the motionless charged body we get the dependence

$$J = J(q,\mathbf{v}). \tag{3}$$

This is the result of the first step.

The next step consists of the fact that the conductor with current and moving charged body acts on a magnet. This action force depends on the current magnitude J, its orientation, and distance $\mathbf{R}$ to the magnet. Thus the moving charged body force on the magnet is expressed

$$\mathbf{F}_m = \mathbf{F}_m(J,\mathbf{R}) \tag{4}$$

and represents the result of the second step.

The moving charged body will act on the motionless magnetic pole when this action is defined by the force (4). But the body is moving, the distance $\mathbf{R}$ to the magnet changes; this is why the action will be variable.

The third step resides in the fact that if there is a variable magnetic action at a spatial point, the electromotive force appears at this point. In other words, the charged body located at this point will be under action. If the magnetic action variability is created by the magnet motion, the electrical force magnitude will depend on magnetic force and its velocity, and it will be expressed as

$$\mathbf{F}_e = \mathbf{F}_e(\mathbf{F}_m,\mathbf{v}). \tag{5}$$

If the force $\mathbf{F}_m$ on the magnetic pole is produced by the moving charged body, the force $\mathbf{F}_e$ will express this body action on the motionless charged body which placed instead of the magnetic pole. Dependence (5) is the third step result. It expresses the moving charged body force on the motionless one while the motionless body force on the moving one — as known from the third law of motion — will be equal to the first force and opposite to it.

Descriptions of facts exist in physics, and they are known as laws. They do not include the charge magnitudes but density ρ which is bound up with the charge as $q_1 = \int\int\int \rho dV$. The force magnitude on the motionless body with charge q_2 — according to Coulomb's law — is bound up with the density ρ as follows:

$$\operatorname{div} \mathbf{F} = \frac{4\pi q_2}{\varepsilon}\rho .$$

Hence the current compared in action on the magnet to the charged body motion will be recorded as the charge change velocity in time at the magnetic point

$$J = \frac{dq}{dt} .$$

After differentiation and manipulation, the following will be formulated (for detailed derivation, see below and Ref. 4):

$$J = \iiint \operatorname{div} \left[\frac{\varepsilon}{4\pi q_2}\frac{\partial \mathbf{F}}{\partial t} + \rho\mathbf{v}\right] dV. \tag{3a}$$

This expression describes the first fact: the moving charged body with charge q_1 in the ratio of action on the magnet is an equivalent to the current (3a).

The magnitude of the force on the unit magnetic pole is described by the Biot–Savart–Laplace law

$$d\mathbf{H} = J(d\mathbf{l} \times \mathbf{R})/cR^3. \tag{4a}$$

The moving charged body q_1 would act on the magnet with the same force.

This is the second experimental fact description.

The magnetic changes of action are described by Faraday's law of electromagnetic induction:

$$\oint \left[\frac{\mathbf{F}}{q_2}d\mathbf{l}\right] = -\frac{1}{c}\frac{d\Phi}{dt}, \tag{5a}$$

where $\Phi = \mu \int \mathbf{H}d\mathbf{S}$ is a magnetic flux defining the electrical force F on the motionless body with charge q_2. This is the description of the third fact.

The expressions (3a), (4a), and (5a) in a set represent the differential expression for the force acted by the moving charged body on the motionless one:

$$\Delta \mathbf{F} - \frac{1}{c_1^2}\frac{\partial^2 \mathbf{F}}{\partial t^2} = \frac{4\pi q_2}{\varepsilon c_1^2}\frac{\partial \rho \mathbf{v}}{\partial t} + \frac{4\pi q_2}{\varepsilon}\operatorname{grad}\rho, \qquad (6)$$

where

$$\Delta = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}.$$

5. SOLUTION OF THE D'ALEMBERT EQUATION AND THE FORCE OF THE INTERACTION BETWEEN TWO MOVING CHARGES

Equation (6) is called the D'Alembert equation. It is known that this equation without the right side is satisfied by the function F which change is moving with velocity c_1.

The charge density as point object may be written with the help of the δ function:

$$\delta(x - x') = \frac{1}{2\pi}\int_{\infty}^{\infty} \exp i(x - x')k\,dk = \begin{cases} 0 & x \neq x' \\ \infty & x = x' \end{cases}$$

and

$$\int_{-\infty}^{\infty} \delta(x - x')dx = 1;$$

thus

$$\rho = q_1\delta(x - V_xt)\delta(y - V_yt)\delta(z - V_zt),$$

where $\mathbf{r} = \mathbf{i}x + \mathbf{j}y + \mathbf{k}z$, the radius vector of space point; and $\mathbf{r}_e = \mathbf{i}V_xt + \mathbf{j}V_yt + \mathbf{k}V_zt$, the radius vector of charge q_1. Then

$$\rho = \frac{q_1}{8\pi^2}\int_{-\infty}^{\infty} \exp i\Big[k_1(x - V_xt) + k_2(y - V_yt) + k_3(z - V_zt)\Big]dk,$$

where the integral $\int_{-\infty}^{\infty} dk$ is the triple integral $\int\int\int dk_1dk_2dk_3$.

The D'Alembert equation (6) in projections on the coordinate system axis will be written as

$$\Box F_x = \frac{4\pi}{\varepsilon}q_2\left(\frac{\partial \rho}{\partial x} + \frac{1}{c_1^2}\frac{\partial \rho}{\partial t}V_x\right);$$

$$\Box F_y = \frac{4\pi}{\varepsilon}q_2\left(\frac{\partial \rho}{\partial y} + \frac{1}{c_1^2}\frac{\partial \rho}{\partial t}V_y\right);$$

$$\Box F_z = \frac{4\pi}{\varepsilon}q_2\left(\frac{\partial \rho}{\partial z} + \frac{1}{c_1^2}\frac{\partial \rho}{\partial t}V_z\right),$$

where

$$\Box = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} - \frac{1}{c_1^2}\frac{\partial^2}{\partial t^2},$$

but $c_1 = c/(\mu\varepsilon)^{1/2}$, the speed of electrical action propagation in a medium. Further, the equation is solved only for projection F_x, since for the rest of the projections, the equations are similar. The substitution of density ρ presents:

$$\Box F_x = \frac{q_1q_2i}{2\pi^2\varepsilon}\int_{-\infty}^{\infty} [(1 - \beta_x^2)k_1 - \beta_x\beta_yk_2 - \beta_x\beta_zk_3]$$

$$\times \exp i[k_1(x - V_xt) + k_2(y - V_yt) + k_3(z - V_zt)]dk,$$

where $\beta_x = V_x/c_1$, $\beta_y = V_y/c_1$, $\beta_z = V_z/c_1$. The D'Alembert operator $\Box$ does not depend on integration variables k_1, k_2, k_3. Therefore, we can symbolically write on the right-hand side,

$$F_x = \frac{q_1q_2i}{2\pi^2\varepsilon}\int_{-\infty}^{\infty} [(1-\beta_x^2)k_1 - \beta_x\beta_yk_2 - \beta_x\beta_zk_3]\Box^{-1}\exp i[\ ]dk,$$

where $[\ ] = [k_1(x - V_xt) + k_2(y - V_yt) + k_3(z - V_zt)]$. F_x is known from the definition of $\Box^{-1}\exp i[\ ] = G$. The function G can be found from the equation $\Box G = \exp i[\ ]$, which is the linear differential equation of second order in partial derivatives with the right side. Partial solution of the right side and total solution $\Box G = 0$ in whole comprise this solution. But since $\Box G = 0$ is the solution of zero change density, that is, it gives electrical action from some other source, and according to the task condition there is only one charge in the space, now the total solution of equation without the right side is thrown off, we are interested only in the action of given charge. We find the partial solution in the form of $G = C\exp i[\ ]$. Its substitution in equation $\Box G = \exp i[\ ]$ defines the coefficient

$$C = -\frac{1}{k_1^2 + k_2^2 + k_3^2 - (\beta_xk_1 + \beta_yk_2 + \beta_zk_3)^2};$$

$$G = -\frac{\exp i[\ ]}{k_1^2 + k_2^2 + k_3^2 - (\beta_xk_1 + \beta_yk_2 + \beta_zk_3)^2}.$$

Then

$$F_x = -\frac{q_1q_2i}{2\pi^2\varepsilon}\int_{-\infty}^{\infty} \frac{(1 - \beta_x^2)k_1 - \beta_x\beta_yk_2 - \beta_x\beta_zk_3}{k_1^2 + k_2^2 + k_3^2 - (\beta_xk_1 + \beta_yk_2 + \beta_zk_3)^2}\exp i[\ ]dk$$

$$= -\frac{q_1q_2i}{2\pi^2\varepsilon}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \exp i[k_2(y - V_yt) + k_3(z - V_zt)]\,I_1^1\,dk_2dk_3,$$

where

$$I_1^1 = \int_{-\infty}^{\infty} \frac{[(1-\beta_x^2)k_1 - (\beta_x\beta_y k_2 + \beta_x\beta_z k_3)]\exp i(x - V_x t)k_1}{k_1^2 - \beta_x^2 k_1^2 - 2\beta_x k_1(\beta_y k_2 + \beta_z k_3) + a^2} dk_1$$

and $a^2 = k_2^2 + k_3^2 - (\beta_y k_2 + \beta_z k_3)^2$.

In the next step we consider the solution in the case of charge motion speed which is less than the speed of light in a given medium, that is, $\beta^2 = \beta_x^2 + \beta_y^2 + \beta_z^2 \le 1$. Under the conditions, $a^2 > 0$. Indeed,

$$a^2 = k_2^2(1 - \beta_y^2) + k_3^2(1 - \beta_z^2) - 2\beta_y\beta_z k_2 k_3$$

may be negative when the third item is positive, for example, β_y, β_z, k_2, and k_3 and have identical signs. Then the increment

$$da^2 = -2(\beta_y k_2 + \beta_z k_3)k_2 d\beta_y - 2(\beta_z k_3 + \beta_y k_2)k_3 d\beta_z$$

during any changes β_y and β_z is negative. But a^2 is between the limits $a^2 = k_2^2 + k_3^2$ under $\beta_y = \beta_z = 0$ and $a^2 = [k_2(1 - \beta_y^2)^{1/2} - k_3\beta_y]^2 > 0$ under $\beta_y^2 + \beta_z^2 = 1$; this monotonous change a^2 in positive limits is evidence of this magnitude positiveness during the whole interval of parameter changes.

Assume that

$$e_1 = (1 - \beta_x^2)^{1/2};\ b = \beta_x(\beta_y k_2 + \beta_z k_3);\ A = x - V_x t,$$

but ξ is a complex number. The integral about the closed path in a complex plane is examined:

$$\oint \frac{(e_1^2\xi - b)\exp iA\xi}{e_1^2\xi^2 - 2b\xi + a^2} d\xi;$$

integrand denominator is equal to zero at the points

$$\xi_{1,2} = \frac{b \pm (b^2 - a^2 e_1^2)^{1/2}}{e_1^2},$$

where

$$b^2 - a^2 e_1^2 = -[(k_2^2 + k_3^2)(1 - \beta_x^2) - (\beta_y k_2 + \beta_z k_3)^2].$$

For the above, if $b^2 - a^2 e_1^2 < 0$, then

$$\xi_{1,2} = \frac{\beta_x(\beta_y k_2 + \beta_z k_3)}{1 - \beta_x^2} \pm \frac{i[(k_2^2 + k_3^2)(1 - \beta_x^2) - (\beta_y k_2 + \beta_z k_3)^2]^{1/2}}{1 - \beta_x^2}.$$

The complex integral is considered on the half-ring of radius R in the upper half-plane

$$\oint = \int_{C_R} + \int_{-R}^{R} = 2\pi i C_{-1}(\xi^+).$$

Thus according to the Jordan lemma,

$$\lim_{R\to\infty} \int_{C_R} \frac{e_1^2\xi - b}{e_1^2\xi^2 - 2b\xi + a^2} \exp(iA\xi\, d\xi)$$

is equal to zero, if $A > 0$ and

$$\lim_{\xi\to\infty} \frac{e_1^2\xi - b}{e_1^2\xi^2 - 2b\xi + a^2}$$

is the finite quantity that we can see from this case. But the Jordan lemma can be used in the lower plane if $A = x - V_x t < 0$:

$$\oint = 2\pi i C_{-1}(\xi^-) = \int_{-C_R} + \int_{-R}^{R}.$$

But as

$$\lim_{R\to\infty} \int_{-R}^{R} \frac{e_1^2\xi - b}{e_1^2\xi^2 - 2b\xi + a^2} \exp(iA\xi)d\xi = I_1^1,$$

in the case $x - V_x t > 0$, we have $I_1^1 = 2\pi i C_{-1}(\xi^+)$, and when $x - V_x t < 0$, $I_1^1 = -2\pi i C_{-1}(\xi^-)$. The definition of deductions C_{-1} gives, for $x > V_x t$,

$$I_1^1 = \pi i \exp\left[i(x - V_x t)\frac{\beta_x\beta_y k_2 + \beta_x\beta_z k_3}{1 - \beta_x^2}\right]$$
$$\times \exp\left\{-(x - V_x t)\frac{[(k_2^2 + k_3^2)(1 - \beta_x^2) - (\beta_y k_2 + \beta_z k_3)^2]^{1/2}}{1 - \beta_x^2}\right\};$$

for $x < V_x t$,

$$I_1^1 = -\pi i \exp\left[i(x - V_x t)\frac{\beta_x\beta_y k_2 + \beta_x\beta_z k_3}{1 - \beta_x^2}\right]$$
$$\times \exp\left\{(x - V_x t)\frac{[(k_2^2 + k_3^2)(1 - \beta_x^2) - (\beta_y k_2 + \beta_z k_3)^2]^{1/2}}{1 - \beta_x^2}\right\}$$

The total solutions may be written as

$$I_1^1 = \pi i \frac{x - V_x t}{|x - V_x t|} \exp\left\{ i(x - V_x t)\frac{b}{e_1^2} - |x - V_x t| \times \frac{[(k_2^2 + k_3^2)(1 - \beta_x^2) - (\beta_y k_2 + \beta_z k_3)^2]^{1/2}}{1 - \beta_x^2} \right\};$$

$$F_x = \frac{q_1 q_2 (x - V_x t)}{2\pi\varepsilon |x - V_x t|} \times \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \exp\left\{ i\left[k_2(y - V_y t) + k_3(z - V_z t) + (x - V_x t)\frac{b}{e_1^2}\right] - \frac{|x - V_x t|}{1 - \beta_x^2}\left[(k_2^2 + k_3^2)(1 - \beta_x^2) - (\beta_y k_2 + \beta_z k_3)^2\right]^{1/2}\right\} dk_2 dk_3;$$

$$F_x = \frac{q_1 q_2 (x - V_x t)}{2\pi\varepsilon |x - V_x t|} \times \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \exp\left\{ i\left[\left[y - V_y t + \frac{x - V_x t}{1 - \beta_x^2}\beta_x\beta_y\right] k_2 + \left[z - V_z t + \frac{x - V_x t}{1 - \beta_x^2}\beta_x\beta_z\right] k_3\right] - \frac{|x - V_x t|}{1 - \beta_x^2} \times \left(1 - \beta_x^2 - \beta_y^2\right)^{1/2} \left[\frac{(k_2^2 + k_3^2)(1 - \beta_x^2) - (\beta_y k_2 + \beta_z k_3)^2}{1 - \beta_x^2 - \beta_y^2}\right]^{1/2}\right\} \times dk_2 dk_3 .$$

The following substitutions are made:

$$L_3 = z - V_z t + \frac{x - V_x t}{1 - \beta_x^2}\beta_x\beta_z;$$

$$L_2 = y - V_y t + \frac{x - V_x t}{1 - \beta_x^2}\beta_x\beta_y;$$

$$A_\pm = \frac{\dfrac{\beta_y\beta_z}{\left(1 - \beta_x^2 - \beta_y^2\right)^{1/2}} \pm i\left[1 - \beta_x^2 - \beta_z^2 - \dfrac{\beta_y^2\beta_z^2}{1 - \beta_x^2 - \beta_y^2}\right]^{1/2}}{\left(1 - \beta_x^2 - \beta_y^2\right)^{1/2}};$$

$$u = \frac{|x - V_x t|}{1 - \beta_x^2}\left(1 - \beta_x^2 - \beta_y^2\right)^{1/2} > 0;$$

$$s^2 = (k_2 - k_3 A_+)(k_2 - k_3 A_-) > 0;$$

$$n = k_2 L_2 + k_3 L_3.$$

Since during changes of k_2 and k_3 in one of the half-planes, for example, $0 < k_2 < \infty$, $-\infty < k_3 < \infty$, the new variables have all their values $0 < s < \infty$, $-\infty < n < \infty$, in the time of integration by n and s it is necessary to double the integral value.

The substitution of enumerated parameters leads to the expression

$$F_x = \frac{q_1 q_2 (x - V_x t)}{2\pi\varepsilon |x - V_x t|}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \exp\left[i(L_2 k_2 + L_3 k_3) - us\right] dk_2 dk_3 .$$

The area elements in coordinates n and s may be determined:

$$dsdn = \left(\frac{\partial s}{\partial k_2}\frac{\partial n}{\partial k_3} - \frac{\partial s}{\partial k_3}\frac{\partial n}{\partial k_2}\right) dk_2 dk_3 = \frac{dk_2 dk_3}{s}\left[k_2(L_3 + L_2 A_g) - k_3(L_3 A_g + L_2 A^2)\right];$$

$$A_g = \frac{\beta_y\beta_z}{1 - \beta_x^2 - \beta_y^2};$$

$$A^2 = \frac{\beta_y^2\beta_z^2}{(1 - \beta_x^2 - \beta_y^2)^2} + \frac{1 - \beta_x^2 - \beta_z^2 - [(\beta_y^2\beta_z^2)/(1 - \beta_x^2 - \beta_y^2)]}{1 - \beta_x^2 - \beta_y^2}.$$

Further, k_2 and k_3 are expressed by s and n:

$$k_2 = \frac{n}{L_2} - k_3\frac{L_3}{L_2};$$

$$s^2 = k_2^2 - 2k_2 k_3 A_g + k_3^2 A^2;$$

$$k_3^2\left[\frac{L_3^2}{L_2^2}+2A_g\frac{L_3}{L_2}+A^2\right]-2k_3 n\left[\frac{L_3}{L_2^2}+\frac{A_g}{L_2}\right]+\frac{n^2}{L_2^2}-s^2=0.$$

Solution of the equation gives

$$k_3=\frac{n(L_3+L_2A_g)\pm L_2(s^2B^2-n^2A_t^2)^{1/2}}{B^2},$$

where

$$B^2=L_3^2+2A_gL_3L_2+A^2L_2^2;$$

$$A_t^2=\frac{1-\beta_x^2-\beta_z^2-\beta_y^2\beta_z^2(1-\beta_x^2-\beta_y^2)^{-1}}{1-\beta_z^2-\beta_y^2};$$

$$A_\pm=A_g\pm iA_t;$$

k_2 is also determined:

$$k_2=\frac{n(L_3A_g+L_2A^2)\mp L_3(s^2B^2-n^2A_t^2)^{1/2}}{B^2}.$$

Substitution of k_2 and k_3 gives

$$dk_2dk_3=\mp\frac{s}{(s^2B^2-n^2A_t^2)^{1/2}}\,ds\,dn.$$

The double signs $\pm$ prove the duality of k_2 and k_3 under the same values of n and s, as mentioned above. From the expression for k_2 and k_3 we see their reality if $s^2B^2-n^2A_t^2\geq 0$; then $|n|\leq sBA_t^{-1}$. Then the force will be

$$F_x=\frac{q_1q_2(x-V_xt)}{\pi\varepsilon|x-V_xt|}\int_0^\infty ds\int_{-\infty}^{\infty}\frac{s\exp(in-us)}{(s^2B^2-n^2A_t^2)^{1/2}}\,dn.$$

The transition to polar coordinates in plane ns is now made.

$$n=r\sin\alpha\,;\quad s=r\cos\alpha;$$

$$dn\,ds=r\,dr\,d\alpha;\quad 0<r<\infty,$$

$$-\arctan B/A_t\leq\alpha\leq\arctan B/A_t=\alpha_0\,.$$

Then the expression for force will have the form

$$F_x=\frac{q_1q_2(x-V_xt)}{\pi\varepsilon|x-V_xt|}\int_{-\alpha_0}^{\alpha_0}\cos\alpha\int_0^\infty\frac{r\exp(i\sin\alpha-u\cos\alpha)r}{(B^2\cos^2\alpha-A_t^2\sin^2\alpha)^{1/2}}\,d\alpha\,dr$$

$$=\frac{q_1q_2(x-V_xt)}{\pi\varepsilon|x-V_xt|}\int_{-\alpha_0}^{\alpha_0}\frac{\cos\alpha}{(B^2\cos^2\alpha-A_t^2\sin^2\alpha)^{1/2}}\frac{d\alpha}{(i\sin\alpha-u\cos\alpha)^2}$$

$$=\frac{2q_1q_2(x-V_xt)}{\pi\varepsilon|x-V_xt|}\int_0^{B/A_t}\frac{(u^2-\tan^2\alpha)^2d\tan\alpha}{\left(u^2+\tan^2\alpha\right)^2(B^2-A_t^2\tan^2\alpha)^{1/2}}.$$

Here the substitution (a and b are new parameters) gives:

$$\tan\alpha=\frac{B}{A_t}\sin\gamma\,;\quad a=u^2;\quad b=\frac{B^2}{A_t^2}>0\,;$$

$$F_x=\frac{q_1q_2(x-V_xt)}{\pi\varepsilon|x-V_xt|A_t}\int_0^{\pi/2}\frac{a-b\sin^2\gamma}{(a+b\sin^2\gamma)^2}\,d\gamma\,.$$

It is possible to express this integral through the known integrals

$$I_1''=\int_0^{\pi/2}\frac{a-b\sin^2\gamma}{(a+b\sin^2\gamma)^2}\,d\gamma$$

$$=2a\int_0^{\pi/2}\frac{d\gamma}{(a+b\sin^2\gamma)^2}-\int_0^{\pi/2}\frac{d\gamma}{a+b\sin^2\gamma}\,;$$

$$\int_0^{\pi/2}\frac{d\gamma}{a+b\sin^2\gamma}=\frac{\arctan\left([(a+b)/a]^{1/2}\tan\gamma\right)}{(a^2+ab)^{1/2}}\bigg|_0^{\pi/2}$$

$$=\frac{\pi}{2(a^2+ab)^{1/2}}\,;$$

$$\int_0^{\pi/2}\frac{d\gamma}{\left(a+b\sin^2\gamma\right)^2}$$

$$=\frac{1}{2a(a+b)}\left[(2a+b)\int_0^{\pi/2}\frac{d\gamma}{a+b\sin^2\gamma}+\frac{b\sin\gamma\cos\gamma}{a+b\sin^2\gamma}\bigg|_0^{\pi/2}\right]$$

$$=\frac{2a+b}{2a(a+b)}\,\frac{\pi}{2(a^2+ab)^{1/2}}\,,$$

whence it appears

$$I_1'' = \frac{\pi}{2}\frac{a^{1/2}}{(a+b)^{3/2}};$$

$$F_x = \frac{q_1 q_2(x - V_x t)}{\varepsilon|x - V_x t|}\frac{a^{1/2}}{A_i(a+b)^{3/2}}.$$

Then we realize the substitutions of parameters a, b, A_i, and their transformations:

$$a^{1/2} = u = \frac{|x - V_x t|}{1 - \beta_x^2}(1 - \beta_x^2 - \beta_y^2)^{1/2};$$

$$b = \frac{B^2}{A_i^2} = \frac{(L_3^2 + 2A_g L_3 L_2 + A^2 L_2^2)(1 - \beta_x^2 - \beta_y^2)^2}{(1 - \beta_x^2 - \beta_z^2)(1 - \beta_x^2 - \beta_y^2) - \beta_y^2\beta_z^2};$$

$$a + b = \frac{1 - \beta_x^2 - \beta_y^2}{(1 - \beta_x^2 - \beta_z^2)(1 - \beta_x^2 - \beta_y^2) - \beta_y^2\beta_z^2}$$

$$\times\Big[(1 - \beta_y^2 - \beta_z^2)(x - V_x t)^2 + (1 - \beta_x^2 - \beta_z^2)(y - V_y t)^2$$

$$+ (1 - \beta_x^2 - \beta_y^2)(z - V_z t)^2 + 2\beta_x\beta_y(x - V_x t)(y - V_y t)$$

$$+ 2\beta_x\beta_z(x - V_x t)(z - V_z t) + 2\beta_y\beta_z(y - V_y t)(z - V_z t)\Big].$$

After control in reverse order we see that it is equal to

$$a + b = \frac{1 - \beta_x^2 - \beta_y^2}{(1 - \beta_x^2 - \beta_z^2)(1 - \beta_x^2 - \beta_y^2) - \beta_y^2\beta_z^2}$$

$$\times\ \{(\mathbf{r} - \mathbf{V}t)^2 - [\boldsymbol{\beta} \times (\mathbf{r} - \mathbf{V}t)]^2\};$$

$$F_x = \frac{q_1 q_2(x - V_x t)\dfrac{|x - V_x t|}{1 - \beta_x^2}\left(1 - \beta_x^2 - \beta_y^2\right)^{1/2}}{\varepsilon|x - V_x t|\left[\dfrac{\left(1 - \beta_x^2 - \beta_z^2\right)\left(1 - \beta_x^2 - \beta_y^2\right) - \beta_y^2\beta_z^2}{\left(1 - \beta_x^2 - \beta_y^2\right)^2}\right]^{1/2}}$$

$$\times\frac{1}{\left[\dfrac{1 - \beta_x^2 - \beta_y^2}{(1 - \beta_x^2 - \beta_z^2)(1 - \beta_x^2 - \beta_y^2) - \beta_y^2\beta_z^2}\right]^{3/2}\left\{(\mathbf{r} - \mathbf{V}t)^2 - \left[\boldsymbol{\beta} \times (\mathbf{r} - \mathbf{V}t)\right]^2\right\}^{3/2}}.$$

But since

$$(1 - \beta_x^2 - \beta_z^2)(1 - \beta_x^2 - \beta_y^2) - \beta_y^2\beta_z^2 = (1 - \beta_x^2)(1 - \beta^2),$$

then

$$F_x = \frac{q_1 q_2(x - V_x t)(1 - \beta^2)}{\varepsilon\{(\mathbf{r} - \mathbf{V}t)^2 - [\boldsymbol{\beta} \times (\mathbf{r} - \mathbf{V}t)]^2\}^{3/2}}.$$

F_y and F_z will have analogous solutions. Therefore, the influence of a uniformly and rectilinearly moving charge with speed **V** can finally be written in the form

$$\mathbf{F} = \frac{q_1 q_2(\mathbf{r} - \mathbf{V}t)(1 - \beta^2)}{\varepsilon\{(\mathbf{r} - \mathbf{V}t)^2 - [\boldsymbol{\beta} \times (\mathbf{r} - \mathbf{V}t)]^2\}^{3/2}}.$$

If $\mathbf{R} = \mathbf{r} - \mathbf{V}t = \mathbf{r} - \mathbf{r}_q$ is the vector from charge q_1 to charge q_2, then moving about it charge q_1 acts by force on charge q_2:

$$\mathbf{F} = \frac{q_1 q_2(1 - \beta^2)\mathbf{R}}{\varepsilon[R^2 - (\boldsymbol{\beta} \times \mathbf{R})^2]^{3/2}}, \tag{7}$$

where **R** is the distance from the moving body to the motionless body, and $\beta = v/c_1$ is the relativistic velocity.

6. THE FORCE OF THE INTERACTION BETWEEN THE MAGNET AND MOVING CHARGE

As a result of eliminating F/q_2 from Eqs. (3a), (4a), and (5a), we get the equation for magnetic strength created by moving charge:

$$\Delta\mathbf{H} - \frac{1}{c_1^2}\frac{\partial^2\mathbf{H}}{\partial t^2} = \frac{4\pi}{c}\operatorname{rot}(\rho\mathbf{v}).$$

In a way analogous to that in Sec. 5 deriving the solution of this equation with the help of the δ function, we get the expression for the moving point charged body force of the action on the single magnetic pole:

$$\mathbf{H}_q = \frac{q_1(1 - \beta^2)(\boldsymbol{\beta} \times \mathbf{R})}{(\varepsilon\mu)^{1/2}[R^2 - (\boldsymbol{\beta} \times \mathbf{R})^2]^{3/2}}. \tag{8}$$

The force of the action on the moving particle will be opposite to the force created by this particle. Therefore, changing the sign in expression (7) and simultaneously substituting the new distance **R** from the motionless body to the moving body which is opposite to the previous one, we shall formulate the same expression (7) for the force action on the moving body.

It is more difficult to obtain the magnetic force action on the moving body from the expression (8), because this expression describes the moving particle force action on the unit point magnetic pole. Since the magnet is characterized by the intensity **H** (by the force on the unit point pole) in its surrounding space points, the magnetic force action on the particle depending on **H** must be calculated. In this case it is necessary to calculate the particle force action on the magnet with the finite sizes using (8) and to take the magnitude opposite to this force. It will be the magnetic force action on the particle including this magnet intensity **H**. For the different magnets the expressions will differ, but all of them can be described with sufficient accuracy by the common expression. Let us derive it.

If an elementary particle of a magnetic pole has the magnetic charge dM, then the particle, in accordance with (8), acts with the force

$$d\mathbf{F}_{dM} = \mu dM \cdot \mathbf{H}_q = \frac{q_1\mu(1 - \beta^2)(\boldsymbol{\beta} \times \mathbf{R})dM}{(\varepsilon\mu)^{1/2}R_v^3}, \quad (9)$$

where $R_v = [R^2 - (\boldsymbol{\beta} \times \mathbf{R})^2]^{1/2}$. From the other side this element dM creates the magnetic strength $d\mathbf{H}$ in the point of particle being

$$d\mathbf{H} = [dM(-\mathbf{R})]/R^3. \quad (10)$$

If we substitute dM into (9) and take into account that $\boldsymbol{\beta}/(\varepsilon\mu)^{1/2} = \mathbf{v}/c$, we get

$$d\mathbf{F}_{dM} = -\mu\frac{q_1(1 - \beta^2)R^3}{cR_v^3}(\mathbf{v} \times d\mathbf{H}). \quad (11)$$

The force on the particle from element dM will be inverse to (11):

$$d\mathbf{F}_q = -d\mathbf{F}_{dM} = \mu\frac{q_1(1 - \beta^2)R^3}{cR_v^3}(\mathbf{v} \times d\mathbf{H}). \quad (12)$$

But the force on the particle from the whole magnetic pole M will define after the integration (12) by all elements:

$$\mathbf{F}_q = \mu\frac{q_1(1 - \beta^2)}{c}\left[\mathbf{v} \times \int_M \frac{R^3}{R_v^3}d\mathbf{H}\right]. \quad (13)$$

Distances R and R_v between particle q_1 and magnetic pole elements dM are in the integral. Therefore, the force will depend on the configuration of the magnetic pole. But since it is accepted to express the magnet influence through magnetic strength H, then in the first approximation we will assume that

$$\int_M \frac{R^3}{R_v^3}d\mathbf{H} \approx \mathbf{H}. \quad (14)$$

After substituting (14) in (13) we get the expression

$$\mathbf{F} = (\mu q/c)(1 - \beta^2)(\mathbf{v} \times \mathbf{H}). \quad (15)$$

The expressions for the force of action on the moving particle from the charged body (7) and magnet (15) at low particle motion velocity $\beta \to 0$ coincide with Coulomb's law (1) and the Lorentz force

$$\mathbf{F} = (\mu q/c)(\mathbf{v} \times \mathbf{H}),$$

respectively, but at velocities approaching velocity c_1 of electromagnetic wave propagation in the medium ($\beta = \mathrm{v}/c_1 \to 1$), these expressions produce forces equal to zero.

Thus the obtained descriptions of the interactions between the moving bodies correlate with observation. With the help of this description, particle motion in accelerators can be calculated. Examples are given below.

7. CALCULATION OF PARTICLE MOTION IN MODERN ACCELERATORS, BASED ON THE NEW DESCRIPTION

Most of the current accelerators produce acceleration of charged particles by acting the charged bodies on them. Accelerators are made such that the acceleration force is directed along the particle velocity.

First, we consider a charged particle with mass m_1 with acceleration activated by the point charged object with the mass $m_2 \gg m_1$. Hence the particle acceleration according to expression (7) and Newton's law (2) is

$$w = \frac{q_1 q_2(1 - \beta^2)}{\varepsilon m_1 x^2}, \quad (16)$$

where x is the distance from the object to the particle, along which the velocity and acceleration are directed. Solving this differential expression [$w = d^2x/dt^2$, $\beta = (1/c_1)(dx/dt)$] we obtain the expression for the particle velocity:

$$\mathrm{v}^2 = c_1^2 - (c_1^2 - \mathrm{v}_0^2)\exp\frac{2q_1}{m_1 c_1^2}\left[\frac{q_2}{\varepsilon x} - \frac{q_2}{\varepsilon x_0}\right] \quad (17)$$

depending on the distance x from the object, if the particle had the velocity v_0 at the initial distance x_0. The value $q_2/\varepsilon x = V$ in the expression represents the electrical end point potential, and $q_2/\varepsilon x_0 = V_0$ is the initial point potential. Hence the difference between these two potentials (voltage) can be written as

$$U = V - V_0 = (q_2/\varepsilon x) - (q_2/\varepsilon x_0),$$

and velocity expressed as

$$\mathrm{v}^2 = c_1^2 - (c_1^2 - \mathrm{v}_0^2)\exp(2q_1 U/m_1 c_1^2). \quad (18)$$

This expression contains only the voltage of the acting object which the particle passes through. Therefore, in the case of nonpoint action objects, using this expression (18), the acquired particle velocity can also be defined according to the voltage U which the particle will go through. The calculations show that the calculated velocity magnitude is slightly different from the magnitude that would be obtained by this object force definition. That is why the expression can be used with sufficient accuracy for the calculation of the action on a particle by any object.

Let us consider this expression's peculiarities. First, expression (18) shows that no matter how large the voltage U the particle passed through, its velocity would never exceed the velocity c_1. Therefore, in the established particle energy definition method, when the particle charge q is multiplied by the voltage U through which it has passed, that is, $E = qU$, this magnitude corresponds to the real particle energy. Because the particle energy after acceleration becomes its kinetic energy $E = T = mv^2/2$. And if the voltage is infinitely large, $U \to \infty$, the particle energy according to (18) will not be infinite — as it is used to consider at present — but it will only approach $E \to mc_1^2/2$.

The electron magnitude $mv^2/2$ is equal to 0.256 MeV. Since the electron in current accelerators cannot reach a velocity higher than c, it will not be able to exceed the energy $mc^2/2$. Since 1 MeV, 100 MeV, 1 GeV energies adopted by the electron characterizes only the voltage sums 10^6 V, 10^8 V, 10^9 V, respectively, through which the particle has passed, we call it relativistic in contrast to the real energy.

The second peculiarity of expression (18) is that the particle passing through the same voltage will get a different increment in velocity and energy. The increment magnitude depends on the initial velocity with which the particle is accelerated. The particle accelerates better when its initial velocity is equal to zero and does not accelerate at all when the initial velocity approaches c_1. Therefore, the relativistic energy does not correspond to the real one, because at the different initial velocities the particle gets the different increments in energy.

We now consider magnetic action on the particle motion. When the particle velocity v is perpendicular to the homogeneous magnetic field **H** and other bodies do not act on the particle, the particle will move in a circle. Actually, when we substitute the force (15) in Eq. (2) and solve the obtained differential particle motion equation, we shall see that particle trajectory is the circumference with radius

$$R = mvc/[\mu qH(1 - \beta^2)]. \qquad (19)$$

Since the particle motion velocity in the circle is $v = \omega R$, the angular particle revolution velocity will be

$$\omega = (\mu qH/mc)(1 - \beta^2). \qquad (20)$$

From the above, the angular velocity — in contrast to the Lorentz force — is not constant: it decreases when the velocity increases. When the particle attains the electromagnetic wave propagation velocity ($\beta \to 1$), the magnetic device with any large intensity H cannot bend the particle trajectory.

Using the particle motion description, when the particle is affected by the electric (18) and magnetic (20) devices, we can discuss the modern particle accelerator schemes.

In the high-voltage electrostatic accelerator the charged particle acceleration is produced by electrically charged assembly parts. Usually the electrode series, plates with holes or tubes, when the potential increases from the previous to the next ones, are used. Passing through the distance between the first electrodes the particle is accelerated under the voltage U_1 action between them. If the initial particle velocity is v_0, its velocity fallen through the second electrode, according to (18), will be

$$v_1 = \left[c_1^2 - (c_1^2 - v_0^2)\exp\frac{2q_1U_1}{m_1c_1^2}\right]^{1/2}. \qquad (21)$$

After passing through the distance between the second and third electrodes with the voltage U_2 the particle will have the velocity

$$v_1 = \left[c_1^2 - (c_1^2 - v_1^2)\exp\frac{2q_1U_2}{m_1c_1^2}\right]^{1/2}. \qquad (22)$$

If we substitute v_1 from (21) into (22), we shall obtain

$$v_2 = \left[c_1^2 - (c_1^2 - v_0^2)\exp\frac{2q_1U}{m_1c_1^2}\right]^{1/2}, \qquad (23)$$

where $U = U_1 + U_2$.

Thus we see that only the voltage between the initial and end electrodes, or total voltage through which the particle has passed, enters into the expression. If the accelerated particle passes through $n + 1$ electrode and total voltage is $U = \Sigma_{i=1}^{n} U_i$, its velocity will be expressed by (18). Therefore, having passage through even the infinite number of electrodes the particle velocity will not exceed c_1.

In the cyclotron, the particle moves in a circle or any other cyclic curve acted on by the magnets with magnetic strength **H** perpendicular to the velocity. There are the electrode pairs in a circle with their potential difference acting on the particle acceleration. Cyclotrons usually have two electrodes — duants consisting of two parts of the small - height cylinder box divided in diameter. The particles revolve inside the duants and come through the slots between them. The duants have the high frequency voltage to increase the particle velocity when it passes through the slot. With φ phase, the acceleration will be produced by the voltage $u = U_m \cos\varphi$, where U_m is the voltage amplitude.

In this cyclotron type the phase voltage in the slot changes with every revolt. When the velocity of the particle increases, its angular velocity, according to (20), decreases. That is why with any following revolt the particle lags behind the previous phase voltage. The particle will pass through the total voltage enduring n revolts:

$$U = \sum_{i=1}^{n} u = U_m \sum_{i=1}^{n} \cos\varphi_i .$$

The finite particle velocity will be defined by expression (18). Since the phase increases, the acceleration usually begins at the negative phase $\varphi > -\pi/2$ and finishes at the positive phase $\varphi < \pi/2$. The finite particle velocity can be accurately defined by the consecutive calculations after every slot passing through by the particle. Knowing the initial velocity v_0 of the particle introduced into the accelerator and the initial phase φ_0 voltage, using expression (18), we can define the particle velocity v_1 passing through the first slot. Using φ_1 and expression (20), the angular velocity ω_p can be defined. Knowing the difference ω_p and circular frequency voltage $\omega = 2\pi f$, we can define the phase voltage φ_2 in the second slot. Using φ_2 and v_1 and expression (18), the velocity after the second slot is defined again. Continuing the calculations, we can calculate the finite particle velocity. These calculations are better performed by computers.

A synchrocyclotron or phasotron differs from a cyclotron, which changes the accelerating voltage frequency corresponding to the angular particle velocity changes. Using expression (20), the frequency must be changed in this way:

$$f = \frac{\omega_p}{2\pi} = \frac{\mu q_i H}{2\pi m_i c}(1 - \beta^2) .$$

In the modern accelerators, due to the uncontrollable change ω_p, the particle velocity changes with the phase oscillation.

In the cyclotron and phasotron, as expression (19) shows, the trajectory radius increases along with the particle acceleration. In synchrotron and synchrophasotron the trajectory radius is constantly maintained in order not to set the magnet through the whole trajectory radius change distance. As expression (19) shows, it is necessary to increase the magnetic intensity according to the law along with the particle velocity acceleration for this process:

$$H = \frac{m_1 c}{\mu q_1 R_a} \frac{v}{(1 - \beta^2)} ,$$

where R_a is the accelerator radius. But since the particle velocity increases while its trajectory radius does not change, the particle angular velocity begins to increase and the accelerating voltage phase begins to decrease. In synchrophasotrons — unlike in synchrotrons — the accelerating voltage frequency has to be changed for this purpose. All the above-mentioned cyclic accelerators, excluding the cyclotron, operate in the pulse mode.

In the linear accelerators particle acceleration is rectilinear. The voltage on the pipe electrodes (drift tubes) or in the wave guide is produced by the high-frequency electromagnetic field. The finite velocity is defined by expression (18), where U is the total voltage through which the particle passes.

8. ATTAINMENT OF SUPERLIGHT VELOCITY

We studied the main accelerator types relying absolutely on the new description based upon classical mechanics. Therefore, the velocity magnitude limitation existed in the theory of relativity description of the charged body interactions can be rejected. Without taking into account this limitation we can say that the particles are constantly moving in the world around us. Their velocity, relative to the same particles moving in the counterdirection, is higher than the velocity of light. The relative superlight particle velocities also exist in the contrary beam installations. The purpose of our study is the description of the method of particle production with superlight velocity relative to the installation. It is sufficient to provide the conditions for this purpose when the particle is accelerated by the object moving relative to the unit in the particle acceleration direction. So the particle can be accelerated by this object to the velocity relative to it. Relative to installation, the particle velocity will be equal to the sum of the object velocities u and c_1, that is, $v = c_1 + u$.

This is the superlight velocity attainment method. In spite of the simplicity, it cannot be accepted by the theory of relativity because the latter forbids motion faster than light. Consequently, there is another velocity addition formula where the sum of the velocities c and u cannot exceed the velocity c. Therefore, we considered the new description of the acceleration calculation, gave the argument against the theory of relativity's unnatural method, and proved the finite velocity hypothesis incorrect.

The bunch of charged particles produced, for example, in modern accelerators, can be regarded as the high-speed affecting object. This bunch of N particles each with charge q will have the total charge $Q_1 = qN$. If the second bunch with charge Q_2 has the opposite sign, and moves in front of Q_1, it will produce to Q_1 the relative velocity v_r defined by expression (17). For this purpose, the bunches are regarded as the points; the affecting bunch has mass M_2 greater than the accelerated bunch mass M_1. In this case the affecting bunch retardation can be ignored. The bunch accelerates until it approaches the affecting bunch. Considering the distance between their centers at this moment equal to the largest of their diameters d, and considering the proton and electron bunches with the particle charge e, the following relation will express the relative accelerated bunch velocity:

$$v_r^2 = c^2 - c^2 \exp\left[-\frac{2q_1 N_2}{m_1 c^2 d}\right] . \quad (24)$$

Here, N_2 is the number of affecting bunch particles, m_1 is an accelerated bunch particle mass; the acceleration is produced in the medium, where $\varepsilon = \mu = 1$.

As a result of expression (24), the electron bunch can be accelerated by the proton bunch with the number of particles $N_2 \geq 4 \times 10^{12}$ to the velocity $v_r = 0.3c$. The proton bunch can reach the same velocity when it is accelerated by the electron bunch with the number of particles $N_2 \geq 6.2 \times 10^{14}$. In this case, the bunch sizes have diameter d of approximately 2 cm.

Since the particle bunches with velocity close to the velocity of light can be obtained in modern accelerators, then after the acceleration by the moving bunch, the accelerated particles will have the velocity relatively to the installation $v = c + 0.3c = 1.3c$.

This velocity is significantly higher than the velocity of light. Therefore, even in the case of not high vacuum in the installation the particle deceleration by the superlight radiation (the so-called Čerenkov radiation) will not decrease this velocity to the prelight velocity.

After that, when the accelerated bunch reaches the affecting one, it will be ahead of it and decelerate. Therefore, it is necessary to avert the further interactions between the bunches. It can be done in different ways. If the bunches are acted on by the magnet, the affecting bunch will deviate from the accelerated bunch motion path. In this case, the magnetic strength vector **H** must be perpendicular to the bunch velocity. The calculations show that the accelerated bunch deceleration will decrease when the magnitude of the magnetic strength increases. The electron bunch does not need much strength to accelerate the proton bunch, because the electron mass of the interaction bunch removed from acceleration is very small. But when accelerated by the proton bunch, it is necessary to apply significantly higher magnetic action to remove it from acceleration. The calculations show that the magnitude of the magnetic strength of 15 kg – 20 kg widely applied in the modern accelerators is suitable for this purpose.

The bunches can be separated after the convergence by the electrical action perpendicular to the bunch velocity. The magnetic and electrical forces can be used simultaneously as well.

The accelerated bunch will move with superlight velocity relative to these deviation devices. When the bunch attains the superlight velocity, there is no action on it, and the superlight bunch will not slow down by deviation devices. Therefore, only the bunch acted upon will be led away from the trajectory. Before acceleration it had velocity less than the velocity of light, and after interaction its velocity is less. Therefore, its deviation will be comparatively easy.

As we observed, the superlight electron production requires the proton bunches with the number of particles of the order of 10^{12} - 10^{13}, while for the portion acceleration, electron bunches with the number of particles of the order of 10^{14} - 10^{15} are necessary. With this number of particles the bunches should have sizes of approximately 1 cm – 10 cm.

These proton bunches are currently produced by many large modern accelerators. For example, the authors in Ref. 9 state that the proton synchrotron number of particles comes to 2×10^{12} in pulse. Moreover, it is projected to increase the number of particles in pulse to 5×10^{13}.

The bunches produced in the accumulation rings have even more protons. According to Ref. 10, it is planned to produce 4×10^{14} protons in a bunch.

Therefore, any of these accelerators can accelerate the electrons to the superlight velocity. Even the velocity higher of $1.3c$ can then be attained.

Yet there are no such great possibilities for proton acceleration to the superlight velocities, because it requires 100 times more electrons in a bunch. But since the electron mass is 2000 times less than the proton mass, their repulsion force is greater. Therefore, it is difficult to produce the great electron density in the bunch. Nevertheless, the necessary electron bunches can be produced as the rings. Some investigators managed to produce these rings. For instance, according to Ref. 11, electron rings with 6×10^{12} particles were produced.

Sarantsev[11] produces rings with 10^{13} electrons. These ring sizes can be smaller than 1 mm. Therefore, even they can accelerate the protons to superlight velocity. According to Sarantsev, it is possible to produce rings with the sizes 10^{-3} cm – 10^{-4} cm. These bunches can accelerate the protons to velocities higher than $1.3c$.

Some investigators try to produce electron bunches with an even greater number of electrons. For example, Khodataev[12] assumes that it is possible to produce small bunches with 4×10^{16} electrons. According to Ref. 13, in Russia the bunches with 2×10^{15} electrons have already been produced. Therefore, in the purposeful electron bunch production, their necessary density can be attained in order to accelerate the protons to the velocity of $1.3c$ and higher.

9. MULTISTEP SUPERLIGHT PARTICLE ACCELERATORS

Twice the velocity of light is the highest velocity to which particles can be accelerated. Actually, one bunch can accelerate another relative to itself to the velocity not higher than c_1. The accelerators can produce these bunches with velocity not higher than c_1. With the help of the following multistep accelerator method the limit of twice the velocity of light can be exceeded.

The proton with the velocity of light production requires large accelerators. But it will be more difficult to accelerate heavy ions to superlight velocity, although if the protons or ions are accelerated to this velocity by the electron bunches, it will be significantly easy. The observed electron bunch of 10^{14} – 10^{15} particles can accelerate the proton bunch with the initial velocity of $0.7c$ to the velocity of light.

The proton bunch obtained after the first acceleration can be accelerated again by the electron bunch to the velocity of $1.3c$. If this proton bunch is accelerated by the similar electron bunch again, its velocity will increase as well. In this case at the beginning of acceleration, the protons will have the velocity relative to the electrons $v_0 = 1.3c - c = 0.3c$. When the proton bunch approaches the electron bunch, the relative proton bunch velocity, according to (17), will be $v_r = 0.412c$. That is why, after the first acceleration step the portion bunch will have the velocity of $1.412c$. The acceleration can be done further in this way.

During all acceleration steps, the electron bunches from the same accelerator transmitted in different periods of time can be used. Working in the multistep mode it is possible to use the electron bunches with less than a number of particle order, 10^{13} - 10^{14}. But in this case, more steps are necessary. The bunch intensity can be preferred to the step quantity, and vice versa, according to the difficulties for this unit production.

This multistep acceleration mode permits the acceleration of particles to the velocity of $2c$ and higher. Actually, the superlight electron and proton bunches can be produced. Then they can be brought together again for one to be accelerated by another. And if the velocity of the bunches were $1.5c$, corresponding to the relative velocity of $0.3c$ to the accelerated bunch, its velocity relative to the unit would be $1.8c$. After the second acceleration step, it will have the velocity of $2.012c$, etc.

10. AFTERWORD

We hear every day of some scientists who offer their critique to the theory of relativity, and their works go unnoticed by the scientific community. Wallace[14] attempted to demonstrate that the relative velocity of light is equal to $c \pm$ v. A number of scientists, including Phipps,[15] Wesley,[16] Bergman,[17] and others, attempt to solve problems of physics on the basis of classical notions of space, time, and mass.

Serious criticism of the theory of relativity has been put forward by Coe,[18] Schaozhi and Xiangqun,[19] Howusu,[20] and others. These scientists have come to the same conclusions in different ways. Expression (7) was derived by Barnes *et al.*[21] and Lucas and Lucas[22] by different classical methods, which are also different from my approach. In addition, the authors of Ref. 22 derived expression (8).

In 1989 I wrote in Ref. 23: "I believe that we are at the threshold of revolutionary changes in physics." In 1993 the authors of Ref. 19 offered the following strong words: "In short, special relativity theory seems to stand on shaky foundations. Theoretical science and especially theoretical physics and astrophysics, confronts us with a great revolution. Let us welcome its coming." All the foregoing point out that perhaps we are witnessing a strong revolutionary process of physics.

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Résumé

En se basant sur les travaux de l'auteur en mécanique classique, l'influence sur les particules rapides est examinée. Il est montré que la force qui agit sur une particule change en fonction de leur vitesse pendant que la masse reste constante. Les principes utilisés par les accélérateurs de particules modernes sont examinés dans le cadre de ces nouvelles interactions. Le principe d'accélération de particules au-delà de la vitesse de la lumière est examiné. Les conditions nécessaires pour sa réalisation sont calculées et considérés possibles dans l'état actuel des techniques contemporaines des accélérateurs.

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