THE DIFFERENCE IN NATURE BETWEEN VIRTUAL AND REAL PARTICLES

In the framework of the relativistic model representing the Euclidean space with three real spatial axes and one corresponding to local time, the dynamics of displacements without mass particles in the absence of fields is investigated.

Key words**:** Special Theory of Relativity, local time, invariants of displacements

PROBLEM STATEMENT

The difference in the nature of virtual and real particles follows from the definitions [1, 2]. Namely: for virtual particles the fundamental conservation laws observed for real particles are not followed. The nature and systematisation of virtual and real particles is fully discussed in reviews [3, 4] and forms the basis of the Standard Model. Recently in the literature there are more and more statements about theories outside the Standard Model [5]. This issue is not considered in this paper.

The purpose of this study is to investigate the problem, which can be formulated as follows. Is it possible to find differences in the nature of real and virtual particles without violating the fundamental conservation laws? If we recognize the difference between explanations of natural phenomena and descriptions of the causes of their occurrence, then such a possibility exists. One of the ways of solving this problem is proposed below. It is the result of the study of space-time properties that determine the quantitative content of Heisenberg's uncertainty principle.

SPACE - LOCAL TIME MODEL

In general, the existence of virtual particles is explained by the fundamental uncertainty principle in the formulation of N. Bohr (Heisenberg's fourth uncertainty relation in the interpretation of L. de Broglie). Being an integral part of the description of the microcosm and quantum mechanics, the principle is successfully applied at the molecular level. For example, in the derivation of the Eyring equation in the theory of the activated complex describing the rates and mechanisms of bimolecular chemical reactions [6]. Consequently, the uncertainty principle works in processes involving both virtual and real particles.

Earlier it has been shown [7] that quantum conditions can be deduced from the provisions of the special theory of relativity. For this purpose it was necessary to consider the phenomena not in traditional space - Minkowski spacetime, but space - local time. This model can be used both to describe virtual particles and to explain their occurrence. The model is based on the classical concepts of three-dimensional Euclidean space and time coordinate t. The existence of elementary particles capable of moving as a unit according to a law in differential form is assumed:

$$(cd\tau)^2 = (cdt)^2 - (dx)^2 - (dy)^2 - (dz)^2 . \qquad (1)$$

$d\tau$ – invariant under arbitrary inhomogeneous Lorentz transformations [8], c – the limiting speed (of light). Thus, τ is the local time measured by the clock directly associated with the particle. Considering t as a natural parameter in four-dimensional Euclidean space with coordinates ($c\tau$, x, y, z), we obtain the phenomenon of motion of any particle with a constant limit speed c:

$$\left(c\frac{d\tau}{dt}\right)^2 + \left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2 + \left(\frac{dz}{dt}\right)^2 = c^2 . \qquad (2)$$

This is true both for stationary particles and for those moving with any velocity relative to some inertial reference frame. It should be especially noted that in the system ‘space - local time’ initially the concepts of particle mass, force and field are not introduced [9, 10]. The isotropy of ‘space - local time’ is assumed. This is expressed in the invariance of three-dimensional spaces with respect to infinitesimal rotations of coordinate axes formed by three of four orthors. There are four of them in total:

$$(0,\mathbf{i},\mathbf{j},\mathbf{k})\ \ (\mathbf{h},0,\mathbf{j},\mathbf{k})\ \ (\mathbf{h},\mathbf{i},0,\mathbf{k})\ \ (\mathbf{h},\mathbf{i},\mathbf{j},0)\,, \tag{3}$$

where the notations of orthos are related to the notations of coordinates and radius-vectors as follows:

$$\begin{array}{llll} \mathbf{r}_0 = c\tau\cdot\mathbf{h}, & \mathbf{r}_1 = x\cdot\mathbf{i}, & \mathbf{r}_2 = y\cdot\mathbf{j}, & \mathbf{r}_3 = z\cdot\mathbf{k} \\ r_0 = c\tau, & r_1 = x, & r_2 = y, & r_3 = z \end{array}. \tag{4}$$

According to classical calculations of theoretical mechanics [11], the vector magnitude of angular or rotational momentum is conserved in a closed system. There are four such moments, respectively:

$$\mathbf{l}_0 = \begin{pmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ r_1 & r_2 & r_3 \\ \dot{r}_1 & \dot{r}_2 & \dot{r}_3 \end{pmatrix},\ \ \mathbf{l}_1 = \begin{pmatrix} \mathbf{h} & \mathbf{j} & \mathbf{k} \\ r_0 & r_2 & r_3 \\ \dot{r}_0 & \dot{r}_2 & \dot{r}_3 \end{pmatrix},\ \ \mathbf{l}_2 = \begin{pmatrix} \mathbf{h} & \mathbf{i} & \mathbf{k} \\ r_0 & r_1 & r_3 \\ \dot{r}_0 & \dot{r}_1 & \dot{r}_3 \end{pmatrix},\ \ \mathbf{l}_3 = \begin{pmatrix} \mathbf{h} & \mathbf{i} & \mathbf{j} \\ r_0 & r_1 & r_2 \\ \dot{r}_0 & \dot{r}_1 & \dot{r}_2 \end{pmatrix}. \tag{5}$$

Differentiating the above moments by the natural parameter t gives zero:

$$\dot{\mathbf{l}}_m = 0, \quad m = 0,1,2,3\,. \tag{6}$$

This corresponds to six equations of the form:

$$r_m\ddot{r}_n - \ddot{r}_m r_n = 0 \quad m,n = 0,1,2,3\,. \tag{7}$$

The solution (7) together with (3) gives two types of solutions. The first one is trivial:

$$\ddot{r}_m = 0 \qquad m = 0,1,2,3 \tag{8}$$

it corresponds to the motion along a straight line (geodesic) in tetrameric space, and the second:

$$\sum_{m=0}^{3} r_m \dot{r}_m = 0, \tag{9}$$

corresponds to the motion on the tetrameric sphere. It is obvious that at real values of coordinates for realization of the solution (9) it is necessary to make an assumption about a sign change of the local time of the particle $c\tau$. Nevertheless, quadratic forms are defined in the fundamental equation (1), which gives some freedom in determining the values themselves. The solution includes local time as a cyclic coordinate.

Motion on a tetrameric sphere of radius R formally corresponds to an equation of the form

$$\dot{\mathbf{r}} = -\frac{\mathbf{ur}}{R^2}, \tag{10}$$

where $\mathbf{r}$ is a tetrameric vector of particle position (r_0, r_1, r_2, r_3) relative to its centre, $\mathbf{u}$ is a linear cosymmetric indicator with constant matrix elements according to (7)

$$u_{mn} = r_n \dot{r}_m - r_m \dot{r}_n \tag{11}$$

m – column number, n – line number.

The vector $\mathbf{r}$ is one of the eigenvectors of the indicator $\mathbf{u}^2$. Thus, differentiating equation (10), we can transform it to the form

$$\ddot{\mathbf{r}} = -\frac{\mathbf{r}}{R^2}, \tag{12}$$

which corresponds to the motion in the harmonic potential field. The solutions of the equation are located in one plane, hence, the trajectories of particle motion, according to condition (9), represent plane circles as intersections of the hyperplane with the tetrameric sphere. In the three-dimensional spatial basis this corresponds to circles, ellipses or segments. We will dwell on the last variant in particular, since it is the most elementary variant of motion. The circle of spontaneous motion of the particle is located in the plane formed by the orbits **h** and **i,** thus, we have the following equations of motion

$$x\dot{x} + c^2\tau\dot{\tau} = 0 \qquad x^2 + c^2\tau^2 = R^2 \tag{13}$$

$$x = R\cos\omega t \qquad c\tau = R\sin\omega t \qquad \omega^2 R^2 = c^2 \tag{14}$$

$$\dot{x} = -\omega R\sin\omega t \qquad c\dot{\tau} = \omega R\cos\omega t \tag{15}$$

$$\ddot{x} = -\omega^2 R\cos\omega t = -\omega^2 x\,. \tag{16}$$

Thus, in the simplest two-dimensional 'space-local time' model, one of non-trivial solutions leads to spontaneous motions of particles (or bodies consisting of them). This leads to the appearance of variable momenta. Within some period determined by the field frequency ω of the harmonic potential (12), the direction of the pulses is reversed. Due to the fact that in the motion, according to (13)-(16) non-zero values are defined only for two moments $\mathbf{l}_2$ and $\mathbf{l}_3$ by (5), the direction of the pulse axis in space may not be conserved.

DISCUSSION OF RESULTS

Virtual particles in the considered model possess a true dualism in the interpretation of N. Bohr. Periodically these particles change their state from motionlessness to a wave travelling at the speed of light. The production of the maximum possible kinetic energy by the time period gives the value of Planck's constant. In the state of immobility the virtual particle acquires the maximum value of the observed mass

$$m = \frac{\hbar}{\omega R^2} = \frac{\hbar\omega}{c^2}\,. \tag{17}$$

Virtual particles have a size limit

$$R = \frac{\hbar}{mc}. \tag{18}$$

Spontaneously virtual particles have no possibility to move in R^3 space beyond the value of R defined by equation (18). They possess only momentum

$$L = m\omega R^2, \qquad (19)$$

and also have a variable kinetic momentum

$$p = \omega R \sin \omega t. \qquad (20)$$

They are isotropic in R^3 space, at least in the case of one-dimensional spontaneous motions.

The virtual harmonic field generating these effects creates the modulus of elasticity of space - local time

$$\kappa = m\omega^2 = \frac{\hbar\omega^3}{c^2}. \qquad (21)$$

To find the difference in the nature of virtual and real particles, we can refer to the paper [9] and the monograph [10], where it was shown that the two-body gravitational problem can be solved without involving the forces of fields and curvature of space. For this purpose it is necessary to make an assumption that local time is complex:

$$c\tau = c\left(\tau_R + i\tau_I\right). \qquad (22)$$

Under this assumption, spontaneous motions of elementary particles according to equation (9) can no longer lead to light speeds. The value of the observed mass of real particles, unlike virtual particles, ceases to be variable and becomes invariant. At this motion the same conservation laws are observed.The difference in the nature of virtual and real particles is quantified by the value of the dimensionless factor by inequality:

$$\frac{\hbar}{mRc} = \frac{\hbar\omega}{mc^2} \vee 1. \qquad (23)$$

If this value is more than one, the particle is virtual, if less, it is real.

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