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NEW APPROACH IN TEACHING THE CONCEPT OF FIELD IN PHYSICAL SCIENCES

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Abstract
In this article the concept of field is analyzed from the physical point of view and a new description of this concept is given. Various definitions of the concept of field and the specifics of the theory of relativity are widely presented. Since all physical processes occur in space and time and historically the concept of field was introduced into science to explain instantaneous action over large distances.

Keywords: Field conception, electrical field, magnetic field, electromagnetic field, gravity, field definition.

Introduction

The concept of a field is widely used in physics education. For example, electric field, magnetic field, electromagnetic field, gravitational field. They are used to explain certain events and processes and their practical application forms the basis of modern scientific and technological progress. This article focuses on highlighting the concept of the field in lifelong physics education and its impact on time and space.

From the point of view of modern science, matter exists in two different forms, that is, in the form of matter and field, that is, matter is a reality that does not depend on our consciousness, and manifests itself in the form of substance and field. Hence, energy and momentum are also key properties of fields as well.

It is known that the concept of a field was introduced to explain the transfer of interactions with particles over long distances. Here it is appropriate to recall the work of I. Newton (1641-1727) (Action at a Distance). It is known that Newtonian mechanics is based on the following two axioms:

1. The mass of an object is a measure of its inertia and mutual attraction at the same time.

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2. Gravitational interactions are transmitted instantly through "empty" space.
In this case, "empty" space or "vacuum" means the absence of other material bodies with mass in the space between objects.

2 METHODOLOGIES

Currently, the concept of a field is given different definitions. Ordinary a field is mathematically defined as an arbitrary function or a set of functions of coordinates and time. There is also a scalar field (temperature at different points with uneven heating of the plate), a vector field (for example, the speed of particles moving in a liquid), a physical field (for example, an electromagnetic, gravitational field) [1]. Below we will focus on the physical field. The physical field is a special form of matter, which is a physical system with an infinite number of degrees of freedom [1]. In this case, it is assumed that the space between the particles is filled with a field and that this field serves to transfer the impact (signal) from one particle to another with a limited speed.
Now let's see how the concept of a field is revealed in physics textbooks. In the educational literature, electric and magnetic fields are described as a means of transmitting interaction, a material being. For example, the lines of force of the electric field, which provide the interaction between charged particles, were proposed by the English physicist Michael Faraday (1791-1867), and these lines are considered, conditionally, as a mathematical visualization. A similar situation is observed in foreign textbooks [2,3]: field is considered as a means of interaction carrier in space. This situation leads to the emergence of an abstract concept of the field. This is because such descriptions given to the field in the literature reflect a sense of abstraction.

3 RESULTS

Now let's take a different approach to this issue. It is known that any physical process takes place in space and time. By space as a whole, we mean a three-dimensional homogeneous and isotropic Euclidean space [4]. According to the theory of relativity, the concept of 4-dimensional space-time is used, in which the 4th dimension - time - is inextricably linked with 3 dimensions of space. Studies of processes in the world of particles have shown that the size of space is larger [5], and now science knows that this space is 11-dimensional. Physicists believe that this dimension may have a higher level. Here, 7 dimensions, in addition to

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geometric space and time, refer to the inner (or hidden) spaces, which are included to explain the internal properties of particles.

Let us now take a quick look at the evolution of the concept of space. Initially, space was defined as unchanging, absolute, that is, independently existing space [6]. It is assumed that physical bodies and processes do not affect space. But according to general relativity, space bends around objects of large mass (the sun, stars, planets). That is, objects and processes in space affect the geometry of space.

If the photon with mass m passes the distance Δz in a uniform gravitational field with acceleration g (g-also the force of the gravitational field), it's energy changes to $\Delta E = \Delta mc^2 = h\Delta \nu$, mass changes to $\Delta m = \frac{mg\Delta z}{c^2}$. Since the photon energy is equal to $E = h\nu = mc^2$, under the influence of the acceleration g of the gravitational field, the photon frequency changes by $\Delta \nu = \frac{\nu g\Delta z}{c^2}$. If a photon leaves the gravitational field, that is, emits light from a star, its frequency decreases by $\Delta \nu$. This effect is called "redshift" in the gravitational field. In other words, a photon emanating from a star does some work to overcome the gravitational field of the star, that is, its energy or frequency decreases:

$$\frac{\Delta E}{E} = \frac{\Delta m}{m} = \frac{\Delta \nu}{\nu} = \frac{g\Delta z}{c^2} \equiv \frac{(\varphi_2 - \varphi_1)}{c^2} = \frac{\Delta \varphi}{c^2} \qquad (1)$$

Here, φ - potential of the gravitational field, for a star with mass M and radius R, is defined as follows:

$$\varphi = \frac{GM}{R}$$

It turns out that the photon frequency depends on the potential of the gravitational field. According to Einstein's theory, this frequency change has been confirmed in experiments. So here it seems that the effect of the gravitational field on the process is manifested. Now let's see how this field affects time. To do this, using the above equation (1), we rewrite the expression

$$\frac{\Delta \nu}{\nu} = \frac{\Delta \varphi}{c^2}$$

If $\Delta \nu = \nu_2 - \nu_1$ and frequency ν_2 of illuminator at the altitude is equal to z_2, receiver at the altitude z_1 will consider it as ν_1, and here $z_2 \succ z_1$. Let the potentials

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of the gravitational field at different heights be $\varphi(z_1)$ and $\varphi(z_2)$. By considering $\nu_1 = \frac{1}{\Delta t_1}$, $\nu_2 = \frac{1}{\Delta t_2}$ and $\nu = \frac{1}{\Delta t}$, we'll come to

$$\frac{\nu_2 - \nu_1}{\nu} = \frac{\frac{1}{\Delta t_2} - \frac{1}{\Delta t_1}}{\frac{1}{\Delta t}} = \frac{(\Delta t_1 - \Delta t_2)}{\Delta t_2} = \frac{(\varphi_1 - \varphi_2)}{c^2} \qquad (2)$$

Here we have used the relationship $\Delta t \approx \Delta t_1$. Considering that $\frac{\varphi_1 \varphi_2}{c^4}$ is small in the last expression (2), it can be written in the following form

$$\frac{\Delta t_1}{\Delta t_2} = 1 + \frac{(\varphi_1 - \varphi_2)}{c^2} \approx (1 + \frac{\varphi_1}{c^2})(1 - \frac{\varphi_2}{c^2}) \qquad (3)$$

(3) - approximate expression. Using

$$(1 - \frac{\varphi_2}{c^2}) \approx \frac{1}{1 + \frac{\varphi_2}{c^2}}$$

we can right it in the following symmetrical way

$$\frac{\Delta t_1}{\Delta t_2} = \frac{1 + \frac{\varphi_1}{c^2}}{1 + \frac{\varphi_2}{c^2}} \qquad (4)$$

Hence, it is clear that, we see $\Delta t_1 = \Delta t_2$ in the case when (2) and (4) are not a gravitational field or if this field is uniform $(\varphi_1 = \varphi_2)$. If $\varphi_2 \succ \varphi_1$, then we have $\Delta t_2 \succ \Delta t_1$. That is, when light enters a strong gravitational field from a weak gravitational field, its "period" increases, and there are fewer "periods" on the time axis. This means that the speed of a clock in a gravitational field slows down more than in free space, and the passage of time slows down.

Consider the effect of a similar gravitational field on space. It is known from the special theory of relativity that the interval of events for flat space in inertial reference frames ds is an invariant quantity

$$ds^2 = c^2 d\tau^2 - (dx^2 + dy^2 + dz^2) = c^2 d\tau^2 - dl^2 \qquad (5)$$

That is, in the Lorentz transformations, this value is constant. We have considered the change in the time interval $d\tau^2$ in the gravitational field. Here, based on (4),

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the relation $\Delta\tau = (1+\frac{\varphi}{c^2})\Delta t$ is appropriate. For this reason, in order not to change ds^2, the interval $dl^2 = dx^2 + dy^2 + dz^2$ must change in the gravitational field and the invariance ds^2 of both limits must be mutually compensated.

Let's make the following changes:

$$c^2 d\tau^2 = (1+\frac{\varphi_4}{c^2})^2 c^2 dt^2 \approx (1+\frac{2\varphi_4}{c^2})c^2 dt^2 = (1+2\varphi_{44})dx_4 dx_4 \qquad (6)$$

here φ_{44} - the component of gravity corresponding to time. Also, let's write the expression relatively to the coordinates of space dx_1, dx_2, dx_3 as in (6)

$$-dl^2 = (1+\frac{\varphi_1}{c^2})^2 dx_1^2 + (1+\frac{\varphi_2}{c^2})^2 dx_2^2 + (1+\frac{\varphi_3}{c^2})^2 dx_3^2 \approx$$
$$\approx (1+2\varphi_{11})dx_1 dx_1 + (1+2\varphi_{22})dx_2 dx_2 + (1+2\varphi_{33})dx_3 dx_3 \qquad (7)$$

Taking into account (6) and (7), we write the interval between events in the presence of a gravitational field as follows, combining them, we get

$$ds^2 = (1+2\varphi_{11})dx_1 dx_1 + (1+2\varphi_{22})dx_2 dx_2 + (1+2\varphi_{33})dx_3 dx_3 + (1+2\varphi_{44})dx_4 dx_4 \qquad (8)$$

Let's unify the expression (8)

$$ds^2 = \sum_{\alpha,\beta}(1+2\varphi_{\alpha\beta})dx_\alpha dx_\beta, \alpha,\beta = 1,2,3,4, \qquad (9)$$

Let's shorten the expression and get

$$ds^2 = g_{\alpha\beta}dx_\alpha dx_\beta, \qquad (10)$$

here $g_{\alpha\beta} = 1+2\varphi_{\alpha\beta}$ is called the metric tensor or space-time metric in the presence of gravity. The sum of the repeated indices in (10) is taken. For flat space (Minkowski space), where the gravitational field can be ignored, based on (5), the metric $g_{\alpha\beta}$ is determined as following

$$g_{11} = g_{22} = g_{33} = -1, \; g_{44} = 1 \qquad (11)$$

When $\alpha \neq \beta$, then $g_{\alpha\beta} = 0$. Here $g_{\alpha\beta} = 1+2\varphi_{\alpha\beta}$ is a metric tensor of space-time, characterizes its curvature. The last expression represents the interval between two events for not curved, flat space. Based on this, the metric properties (curvature) of space depend on the potential of the gravitational field.

Such curved spaces are called Riemannian spaces or non-Euclidean spaces [13]. Huge objects, due to their mass, have a gravitational field - a "gravitational charge". The magnitude of the force acting on a body with a mass m in a field is determined by the expression

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$$F = G\frac{M \cdot m}{r^2}$$

The gravitational field is typical for objects of any mass. But in the world of elementary particles, which are objects of very small mass, the influence of this field is so weak that it can be ignored. On the other hand, in Newtonian mechanics, it is assumed that the motion of bodies does not affect the properties of space, and this is indeed true for the phenomena studied by mechanics.

Now let's look at the electric field created by a stationary electric charge. It is known that an electric field is characterized by two values of the electric field strength ($\vec{E}$) and the electric field potential (φ). For example, let $+q$ be a positive charge. This value of the strength of the electric field created by the charge is determined by the expression

$$E = k\frac{q}{r^2}$$

Or the expression of the electric field potential generated by it will have the following form.

$$\varphi = k\frac{q}{r}$$

According to these expressions, $\vec{E}$ and φ are meaningful at every point around the charge. For this reason, it

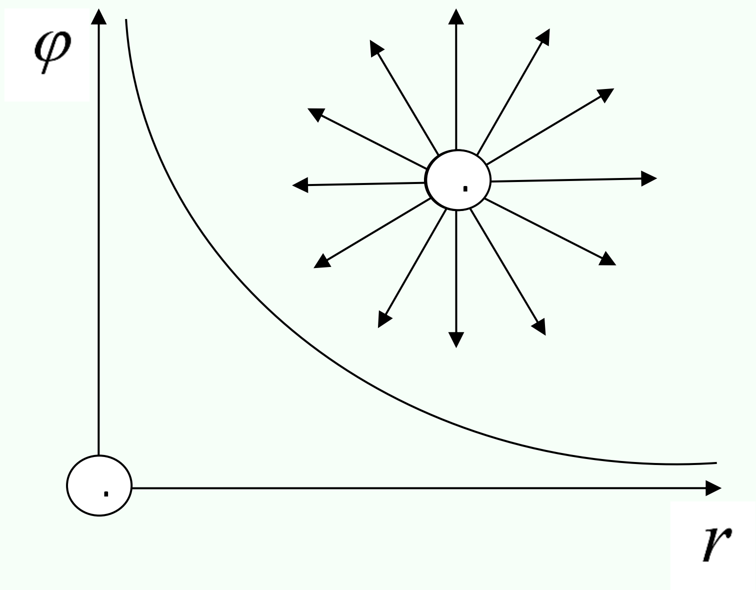

Figure 1. Dependence of the potential of φ on the distance

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cannot be said that the electric field around the charge is uniform.

Also, the magnitude of the magnetic field around the DC conductor is represented as

$$B = \frac{\mu_0 \mu}{2\pi r} I$$

In this case, too, it cannot be said that this field is uniform, because the magnetic induction vector $\vec{B}$ at each point in space around the conductor with current has a different value. We know that electric and magnetic fields are special manifestations of a single electromagnetic field. A system of charged particles creates an electromagnetic field around itself. This field has components $\vec{E}$ and $\vec{B}$. These vectors also have a value at every point in space, and these values are not equal. In this sense, the electromagnetic field is inhomogeneous in this case as well. Now let's apply these three non-uniform fields to space. We know that an electric charge is a separate substance, a being and an inherent property of a particle. The particles can be uncharged, but the electric charge cannot exist separately, independently, without a particle. Where there is an electric charge, there will be an electric field around it. Therefore, it can be assumed that the electric charge changes the properties of the surrounding space. That is, the points in space around the charge are not equally strong (homogeneous), and Galilean or Lorentz transformations remain inappropriate. In the same way, the space around an electric current or a system of charged particles also changes its properties and remains homogeneous. But the change in spatial properties under the influence of a stationary electric charge and electric current is of a different nature. The vector $\vec{E}$ should not be twisted, and the vector $\vec{B}$ should be twisted. The $\vec{E}$ and $\vec{B}$ components of the electromagnetic field must rotate. At large distances from sources (electric charge, electric current, and a system of charged particles), the change in spatial properties is almost imperceptible. Therefore, it is really inappropriate to assume that physical bodies and processes do not exert their influence on space. As space is curved under the influence of large masses - "gravitational charges", so it can be assumed that the space around the electric charge and currents changes its properties. For this reason, we can consider the field as an “excited” state of space that has changed its properties. Electric charge, electric current (direct or alternating), a system of charged particles or mass - "gravitational charge" - cause a change or "excitement" of space, and the nature of the "excitement" of space under their influence also changes. The greater the

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electric charge, electric current, or mass, the greater the curve of this "excitement". That is, for a point in space, the values that characterize this "excitement", the curvature, are also will be bigger

1. $q_1 \prec q_2 \prec q_3 \prec ...$
$\vec{E}_1 \prec \vec{E}_2 \prec \vec{E}_3 \prec ...$
2. $I_1 \prec I_2 \prec I_3 \prec ...$
$\vec{B}_1 \prec \vec{B}_2 \prec \vec{B}_3 \prec ...$
3. $M_1 \prec M_2 \prec M_3 \prec ...$
$\vec{F}_1 \prec \vec{F}_2 \prec \vec{F}_3 \prec ...$

That is, the energy of any field depends on the degree of "excitement" of space.

3 Discussion and Conclusion

Now let us compare this situation with the definitions given in the area [1]. According to the definition in [1], the field is considered mathematically in terms of the coordinates $\vec{r} = x, y, z$, and t is an arbitrary function or set of functions of time. This definition is valid if we consider that a function is a one-to-one relationship based on a certain regularity between two sets of quantities. This is because one can imagine that the relationship between spatial properties will change depending on the presence and absence of space. From the point of view of quantum field theory [1], the field basically means that the four main interactions in nature occur through force-carrier particles - $8g, \gamma, W^+, W^-, Z^0, G$, and any interaction with particles also occurs through other known particles. For this reason, the space between the particles is filled with a field (force-carrier particles), and this field (force-carrier particles) is said to have the function of transferring the effect from one particle to another at a limited speed. The reason the field is defined here as a physical quantity with an infinite degree of freedom is because interactions occur through intermediate particles, and their number is very large. In general, quantum field theory is a fundamental physical concept based on the study of processes in the world of particles, and this theory has nothing to do with the problem we are considering.
According to Einstein, the metric properties (curvature) of space-time (four-dimensional space-time) depend only on the force of gravity.

However, the inability to compare the expressions of gravity, electric and magnetic fields, and to condense large amounts of electric charges in nature means that these fields cannot significantly change the space like the gravitational field.

Thus, the electric, magnetic and electromagnetic fields we know can be viewed as curved, excited states that are changed properties of space, such as the gravitational field. The idea that the electromagnetic and gravitational fields presented in the scientific literature are of the same nature also supports this. The opinions present in the scientific literature considering that the electromagnetic and gravitational fields are of the same nature also confirms this.Now let's take a different approach to this issue. It is known that any physical process takes place in space and time. By space as a whole, we mean a

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