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МОДЕЛЮВАННЯ РІВНЯНЬ ЕЛЕКТРОМАГНІТНОГО ПОЛЯ ДЛЯ ПРИСКОРЕННЯ ЕЛЕМЕНТАРНИХ ЧАСТИНОК З ВРАХУВАННЯМ ТЕОРІЇ ВІДНОСНОСТІ

Розглянуто особливості моделювання електромагнітного поля з урахуванням поправок на теорію відносності для прискорення елементарних частинок.

Ключові слова: електромагнітне поле, моделювання, теорія відносності, елементарні частинки.

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ELECTROMAGNETIC FIELD THROUGH RELATIVITY CONCEPT FOR FUNDAMENTAL PARTICLES ACCELERATION SIMULATION.

Considered the electromagnetic field simulation features, taking into consideration the theory of relativity for the acceleration of elementary particles.

Keywords: electromagnetic field, simulation, relativity concept, fundamental particles.

Making particles travel at speeds close that of light is an important condition while investigating quantum properties of our world. There are three known ways to make fundamental particles travel close to speed of light [1]:

- electromagnetic fields;
- magnetic explosions;
- wave particle interaction.

Electromagnetic field is described with the following equations:

$$\overline{E'}_{\parallel} = \overline{E}_{\parallel}\ ,\ \overline{E'}_{\perp} = \gamma(\overline{E}_{\perp} + \bar{v}\times\overline{B}_{\perp}),$$

$$\overline{B'}_{\parallel} = \overline{B}_{\parallel}\ ,\ \overline{B'}_{\perp} = \gamma(\overline{B}_{\perp} - \bar{v}\times\overline{E}_{\perp}).$$

The pertinent static Maxwell's equations are satisfied in both frames [2]:

laboratory frame: $\nabla\cdot\overline{E} = \dfrac{\rho}{\varepsilon_0},\ \nabla\times\overline{B} = \mu_0\overline{J}$,

in the frame of moving charge: $\nabla'\cdot\overline{E'} = \dfrac{\rho'}{\varepsilon_0},\ \nabla'\times\overline{B'} = 0, (\overline{J'} = 0)$.

Invariance of the counted number of photons and the Lorentz-Einstein transformations enable us to derive transformation equations for the physical quantities introduced in order to characterize energy emission and transport in a plane and in a spherical electromagnetic wave propagating in vacuum.

After Maxwell proposed the differential equation model of the electromagnetic field in 1873, the mechanism of action of fields came into question, for instance in the Kelvin's master class held at Johns Hopkins University in 1884 and commemorated a century later.

The requirement that the equations remain consistent when viewed from various moving observers led to special relativity, a geometric theory of 4-space where intermediation is by light and radiation. The spacetime geometry provided a context for technical description of electric technology, especially generators, motors, and lighting at first. The Coulomb force was generalized to the Lorentz force. For example, with this model transmission lines and power grids were developed and radio frequency communication explored.

The question of how an electric field in one inertial frame of reference looks in different reference frames moving with respect to the first is crucial to understanding fields created by moving sources. In the special case, the sources that create the field are at rest with respect to one of the reference frames. Given the electric fieldin the frame where the sources are at rest, one can ask: what is the electric field in some other frame? Knowing the electric field at some point (in space and time) in the rest frame of the sources, and knowing the relative velocity of the two frames provided all the information needed to calculate the electric field at the same point in the other frame. In other words, the electric field in the other frame does not depend on the particular distribution of the source charges, only on the local value of the electric field in the first frame at that point. Thus, the electric field is a complete representation of the influence of the far-away charges.

Alternatively, introductory treatments of magnetism introduce the Biot–Savart law, which describes the magnetic field associated with an electric current. An observer at rest with respect to a system of static, free charges will see no magnetic field. However, a moving observer looking at the same set of charges does perceive a current, and thus a magnetic field. That is, the magnetic field is simply the electric field, as seen in a moving coordinate system.

Maxwell equations in Gauss coordinate system [3]:

$$\partial_\nu F^{\mu\nu} = -\frac{4\pi}{c} J^\mu,$$

$$\partial_\alpha F_{\beta\gamma} + \partial_\beta F_{\gamma\alpha} + \partial_\gamma F_{\alpha\beta} = 0.$$

Thus Maxwell equations corrected for relativity effect will look like [3]:

$$\overline{E'}_\parallel = \overline{E}_\parallel, \quad \overline{B'}_\parallel = \overline{B}_\parallel,$$

$$\overline{E'}_\perp = \frac{\overline{E}_\perp + 1/c\left[\overline{v}\times\overline{B}\right]}{\sqrt{1-\beta^2}}, \quad \overline{B'}_\perp = \frac{\overline{B}_\perp + 1/c\left[\overline{v}\times\overline{E}\right]}{\sqrt{1-\beta^2}}.$$

The relativistic Doppler effect deserves a special review.

The relativistic Doppler effect is different from the non-relativistic Doppler effect as the equations include the time dilation effect of special relativity and do not involve the medium of propagation as a reference point. They describe the total difference in observed frequencies and possess the required Lorentz symmetry.

Doppler effect is observed and treated differently in the view of the limitations and discrepancies of the special relativity. The results of all previous experiments regarding the effect are questioned, as well as practical applications involving the effect, especially those where a high degree of accuracy is critical [4]:

All the above said, relativistic correction for electromagnetic field particle acceleration becomes more and more important when designing particle accelerators. The classical approach has become obsolete as it doesn't take into the consideration neither relativistic speeds correction, nor Doppler effect corrections. The areas becomes more attractive for investigators and simulators.

Література

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