SELF-ENERGY OF PARTICLES IN GENERAL RELATIVITY THEORY

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Submitted 23 March 1967
ZhETF Pis'ma 5, No. 11, 417-418 (1 June 1967)

As is well known, the gravitational self-energy of a point mass diverges in the linear approximation of the gravitation equations. In the nonlinear theory (Einstein's equations) the gravitational mass defect fully offsets the bare mass as the system dimensions tend to zero, and the total mass of such a system vanishes [1]. For a gravitating dust, this problem is not static - such a system, subject to appropriate initial conditions, constitutes a variant of a closed Friedmann world, whose mass, as is well known, is equal to zero [2] even independently of its radius at the given instant of time.

Although allowance for the gravitational field leads to a finite self-energy of a point-like electric charge

$$m = \frac{e}{\sqrt{\kappa}} \approx 10^{-6} \text{ g}, \tag{1}$$

where e is the charge and κ the gravitational constant, even this value is too large compared with the masses of the known elementary particles. It is possible that particles having such large masses exist in nature ("maximons"), but the theory of the masses of ordinary elementary particles still remains a problem. It must be emphasized that the example given above is so far, in fact, the only physical example in which the so-called relativistic regularization works and yields a finite value of the self-mass.

This raises the natural question: how does this finite value of the charged-particle mass change if besides the electromagnetic and gravitational field we allow for a possible action of other fields, too? It is known that, for example, a scalar field, like a gravitational field, leads to a negative sign of the self-energy of its source.

An analysis of the scalar field within the framework of general relativity theory, carried out by Fisner [3] and by Bergman and Leipnik [4], led to solutions that cast doubts on Stueckelberg's old idea [6] of regularizing the classical divergence of a point charge with the aid of a sclar field, since the behavior of a scalar field at zero (at the source) changes essentially in theses solutions.

However, it is shown in [7] that these solutions, although mathematically correct, do not satisfy the requirement of elementary Euclidean behavior at zero. Moreover, the solutions obtained in [7] lead to the following relation between the quantities of interest to us: $D = \kappa^2 m_1^2 + \kappa G^2 - \kappa e^2 = 0$ (D = 0 is the Euclidean condition at zero), or

$$m_1 = \sqrt{\frac{e^2 - G^2}{\kappa}}, \tag{2}$$

G is the scalar charge constant. Consequently, the mass of a source of a static electric and a scalar field, with allowance for the gravitational interaction, can be any quantity smaller than m, depending on the constant G. This observation is of certain methodological interest. The point is that other possible physical fields can also lead, like the scalar and gravitational fields, to a negative contribution to the self-mass. For example, weak four-fermion interactions also make a negative contribution to the self-mass. The existence of other similar interactions with relatively small specific charges is likewise not excluded.

[1] R. Arnowitt, S. Deser, and C. Misner, Phys. Rev. 120, 313 (1960).
[2] L. D. Landau and E. M. Lifshitz, Teoriya polya (Field Theory), Fizmatgiz, 1962.
[3] I. Z. Fisher, JETP 18, 636 (1948).
[4] O. Bergman and R. Leipnik, Phys. Rev. 107, 1157 (1957).
[5] M. A. Markov, Suppl. Progr. Theoret. Phys. Extra Number, 85, 1965.
[6] E. Stueckelberg, Helv. Phys. Acta 14, 51 (1941).
[7] R. A. Asanov, JINR Preprint E2-3108, Dubna, 1967.

FEASIBILITY OF NEGATIVE DIFFERENTIAL CONDUCTIVITY (NDC) CONNECTED WITH AMPLIFICATION OF SOUND IN A SEMICONDUCTOR IN THE PRESENCE OF TRAPS

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Submitted 25 March 1967
ZhETF Pis'ma 5, No. 11, 419-420 (1 June 1967)

We shall show in this note that an increase of the threshold field in the sound amplification coefficient, connected with adhesion of electrons, may result in a dropping section of the voltage-current characteristic of a semiconductor in the acoustic-instability mode.

The expression for the amplification coefficient of ultrasound in a semiconductor containing traps can be represented in the case when $q\ell \ll 1$ (q - wave number of sound wave, ℓ - electron mean free path) in the form [1]:

$$\alpha = \alpha_0 \left(1 - \frac{\mu E}{s} r\right), \tag{1}$$

where $\alpha_0 > 0$ is some constant, μ the electron mobility, s the speed of sound, E the external electric field, and $0 \le r \le 1$ is the adhesion factor, which depends on the sound frequency and on the average electron lifetime.

Thus, the value of the threshold field in the sound amplification coefficient, $E_{cr} = s/\mu r$, turns out to be larger* by a factor $1/r$ than the field in the absence of adhesion. Physically this is connected with the fact that when $q\ell \ll 1$ the sound amplification is due to the formation and supersonic motion of bunches of space charge. It is well known, however (see [2]), that the velocity of these bunches in an electric field is determined by the drift mobility μ_α, which in the presence of adhesion can be appreciably smaller than the mobility μ which determines the drift velocity in a homogeneous electron current (in our case $\mu_\alpha = \mu r$).

Since we are considering the amplification of sound of small amplitude, only a small fraction of all the electrons is gathered into bunches when $E = E_{cr}$, so that the average drift mobility of the majority of the free electrons is μ. It follows therefore that the current at the critical point, $j_{cr} = en\mu E_{cr} = ens/r$, is larger by a factor $1/r$ than the current that would flow in the sample if all the electrons were to drift with the speed of sound.

When $E > E_{cr}$ the sound wave (which may comprise the intrinsic sound fluctuations in the