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[1] J. V. Jelley, J. H. Fruin, N. A. Porter, T. C. Weekes, F. G. Smith, and R. A. Porter, Nature 205, 327 (1965).

[2] I. A. Borzhovskii, V. D. Volovik, and E. S. Shmatko, Izv. AN SSSR ser. fiz., in press.

[3] J. V. Jelley, F. G. Smith, N. A. Porter, T. C. Weekes, R. A. Porter, N. Charman, J. H. Fruin, and B. McBreen, Nuovo Cimento 40, 2 (1965).

[4] G. A. Askar'yan, JETP 41, 616 (1961), Soviet Phys. JETP 14, 441 (1962).

[5] G. A. Askar'yan, JETP 48, 988 (1965), Soviet Phys. JETP 21, 658 (1965).

[6] F. D. Kahn and I. Lerche, Proc. Roy. Soc. 288, 21 (1965).

CONCERNING THE POSSIBLE ROLE PLAYED BY GRAVITATION IN THE PROBLEM OF THE MASS OF AN ELEMENTARY PARTICLE

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One of the problems of field theory is to determine the masses of the elementary particles, i.e., to express them in terms of the interaction constants and the universal constants. Modern quantum field theory, however, lacks for this purpose a constant with the dimension of length, or an equivalent constant, and this in particular is the cause of the presence of divergences in the theory. Attempts are being made at present to find the "elementary length," but this still leaves open an old and fundamental question: Does not allowance for gravitation and for the gravitational constant γ solve this problem? In this note we present some arguments in favor of an affirmative answer to this question.

It is known that by taking γ into account one can construct a length, for example, by one of the following methods:

$$l_1 = ec^{-2}\gamma^{1/2} = 1.38 \times 10^{-34} \text{ cm}, \quad (1)$$

$$l_2 = \hbar^{1/2}c^{-3/2}\gamma^{1/2} = \sqrt{137}\, l_1. \quad (2)$$

The fact that these lengths are exceedingly small is the usual argument for refuting the role of gravitation in the structure of elementary particles. We shall show, however, that one of the recently proposed approaches to the mass problem calls for the involvement of a length just of the order of (1) and (2). We refer to the "dynamic model of elementary particles, based on the analogy with superconductivity" by Nambu and Jona-Lasinio [1]. In this model, the fermion mass comes into play with the aid of a mechanism that is formally analogous to the mechanism responsible for the energy gap in the theory of superconductivity, and the mass m and the constant F of the corresponding interaction are connected by the characteristic relation

$$m = M\exp(-B/F), \tag{3}$$

where B is a constant factor and M is a quantity with the dimension of mass, which must be constructed from the fundamental constants that enter in the theory (in the models considered by Nambu and co-workers, the expressions for the mass diverge and the role of M in (3) is played by the cutoff parameter).

We confine ourselves to the most thoroughly studied electromagnetic interaction. It is fundamental for the electron and apparently also for the muon, and therefore it is natural to attempt to express the masses of these particles in terms of the constants c, $\hbar$, e, and some length L.

Putting $F = e^2/\hbar c = 1/137$ and $M = e^2/Lc^2$, we get

$$m = \frac{e^2}{Lc^2}\exp(-B\hbar c/e^2). \tag{4}$$

Assuming that B does not differ greatly from unity, we arrive at the conclusion that L is several dozen orders of magnitude smaller than the classical radius e^2/mc^2. This condition is satisfied by the constants (1) and (2), and it is therefore natural to choose L to be one of them, possibly with some multiplier. We consider first both possibilities:

$$m = A_1 e\gamma^{-1/2}\exp(-B_1\hbar c/e^2), \tag{5}$$

$$m = A_2 e^2(\hbar c\gamma)^{-1/2}\exp(-B_2\hbar c/e^2). \tag{6}$$

It is easy to verify that the electron and muon masses can be expressed with equal success with the aid of either (5) or (6), the coefficients A and B being each close to unity. It is important, however, that expressions (5) and (6) behave quite differently when $\hbar \to 0$: the former remains constant and the latter diverges. This means that even a classical analysis provides the choice between them. The matter reduces to determining whether the field energy of the concentrated charge remains finite when gravitation is taken into account in classical electrodynamics. This problem has not been acceptably solved as yet, in spite of many attempts. We adhere here to the point of view recently developed in a paper by Peletminskii and the author (to be published), according to which only the field outside the singular surface takes part in the creation of the field mass of a charged particle. It can be shown that only this part of the field participates in the dynamics of the particle. The reason is that the external force action cannot reach the singular surface within a finite time.

The corresponding value of the field mass turns out to be equal to $e\gamma^{-1/2}$. This approach leads, consequently, to the variant (5) and determines the multiplier A_1. We thus have

$$m = e\gamma^{-1/2}\exp(-B\hbar c/e^2). \tag{7}$$

This expression gives the electron mass when B = 0.3581 and the muon mass when B = 0.3192.

We note that (7) coincides, apart from the coefficient B, with Ivanter's empirical formula [2].

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[1] Y. Nambu and G. Jona-Lasinio, Phys. Rev. 122, 345 (1961).
[2] I. G. Ivanter, JETP 36, 1940 (1958), Soviet Phys. JETP 9, 1380 (1958).