

ON THE FUSION OF LIKE-CHARGED PARTICLES IN VACUUM DUE TO THE ATTRACTION OF THEIR INTRINSIC MAGNETIC MOMENTS

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Using the relations of classical electrodynamics, the interaction of point-like charged particles having intrinsic magnetic moments in vacuum was studied. It was found that, at a sufficiently small distance between such like-charged particles, the magnetic attraction between them can exceed their Coulomb repulsion. Based on this, the possibility of the existence of a system of paired electrons in vacuum was demonstrated. Furthermore, the reason for the limitary small (practically point-like) size of a free electron and its resistance to decay, due to the electrostatic repulsive forces it generates, was established.

Keywords: like-charged particles, intrinsic magnetic moments, paired electrons, structure of a free electron.

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1. INTRODUCTION

Based on the relations of classical electrodynamics, a detailed study of interactions of charged bodies, whose motion creates macroscopic magnetic moments, has previously been conducted [1]. However, microparticles with spin also possess intrinsic magnetic moments even at rest [2,3]. The interaction between such intrinsic moments of atoms, for example, determines the magnetic structure of macroscopic objects known as ferromagnetism [4]. At the same time, the study of the interaction of charged microparticles, having intrinsic magnetic moments, in high vacuum conditions is of great interest. Such interactions largely determine the structure of atoms (molecules) [3], as well as subatomic particles [2]. Corresponding theoretical studies of particles with spin are typically conducted using quantum mechanics [3,4].

In this paper, based on well-known relations of classical electrodynamics, we establish new, important features of the interaction of point-like charged particles, having intrinsic magnetic moments, in

vacuum. It is established that, at a sufficiently small distance between such particles with like charges, the magnetic attraction between them can be stronger than their Coulomb repulsion. Based on this, the possibility of the existence of a system of paired electrons in vacuum is demonstrated. Of particular significance is the author's justification for the limitary small (effectively point-like) size of a free electron and its resistance to decay due to the electrostatic repulsive forces it creates.

2. THEORETICAL MODEL

Let us consider a system consisting of a set of n point particles, each of which has its own electric charge e_i and its own magnetic moment μ_i , where $i=1,2,...n$. It is assumed that these particles are in high vacuum conditions and that no external fields act on this system. Then the potential energy U of interaction of such particles in a static state has the following form [1]:

$$U = 0.5 \sum_{\substack{i,j \\ i \neq j}}^n \left\{ \frac{e_i e_j}{R_{ij}} + \frac{[(\mu_i \mu_j) - 3(\mu_i n_{ij})(\mu_j n_{ij})]}{R_{ij}^3} \right\}, \tag{1}$$

where $R_{ij} = R_{ji} = |\mathbf{r}_i - \mathbf{r}_j|$, $\mathbf{n}_{ij} = (\mathbf{r}_i - \mathbf{r}_j)/R_{ij}$, and \mathbf{r}_i is the vector defining the position of the particle $i=1,2,...n$. It is clear that the quantity U (1) is the sum of the potential energies for each pair of particles in the system under consideration.

Therefore, let us first to analyze the system consisting of only two particles, 1 and 2, for which the potential energy U (1) is described by the expression:

$$U = \frac{e_1 e_2}{R} + \frac{\beta}{R^3}, \tag{2}$$

where

$$\beta = [(\mu_1 \mu_2) - 3(\mu_1 \mathbf{n})(\mu_2 \mathbf{n})], \tag{3}$$

$R = R_{12}$, \mathbf{n} is the unit vector between the positions of particles 1 and 2. The value of β (3) is limited by $|\beta| < 4|\mu_1||\mu_2|$ and can be either positive or negative depending on the relative orientation of the magnetic moments of particles 1 and 2, as well as on the projections of these moments μ_1 and μ_2 onto the vector \mathbf{n} between them. As a rule, the Coulomb interaction of charged particles significantly exceeds their magnetic interaction. However, at a sufficiently small distance R between particles, the situation can be reversed since the electrostatic term in relation (2) is proportional to R^{-1} , and the magnetic component $\sim R^{-3}$.

3. PAIRED ELECTRONS

In this regard, let us further consider the case of similarly charged particles 1 and 2, when in the relation (2) $e_1 e_2 > 0$, but the value of $\beta < 0$ (3). Then the qualitative dependence of the potential energy $U(R)$ (2), (3) of these particles on the distance R between them is shown schematically in Fig. 1. This function $U(R)$ (2) reaches a maximum at the certain value $R = R_0$:

$$R_0 = \left(\frac{-3\beta}{e_1 e_2} \right)^{0.5}. \quad (4)$$

Fig. 1 shows that at distances $R > R_0$ (4), the usual Coulomb repulsion between these particles predominates. However, in the region $R < R_0$, the situation reverses, as the attraction of the magnetic moments of these particles proves stronger than their electrostatic repulsion. As these particles approach each other further in the region $R < R_0$ (Fig. 1), their potential energy will decrease, leading to the eventual fusion of the particles.

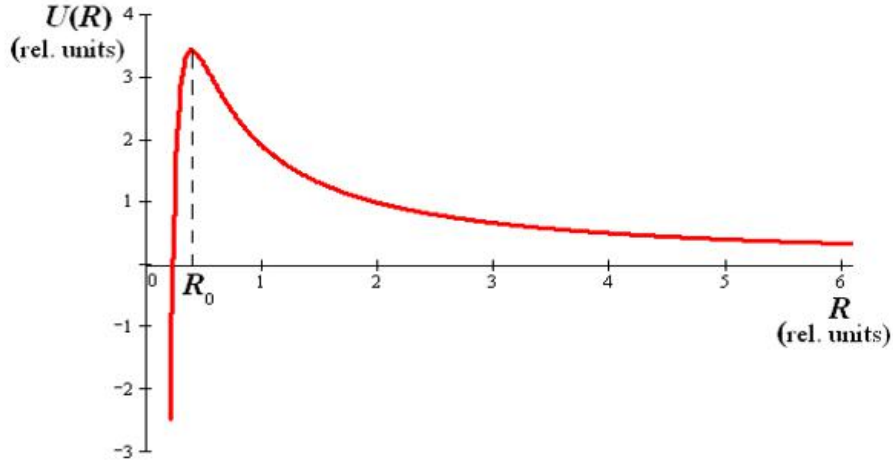


Fig. 1. Qualitative dependence of the potential energy U of particles on the distance R between them.

In particular, let us analyze a system consisting of two electrons whose magnetic moments μ_1 and μ_2 have opposite directions and are orthogonal to the radius vector connecting them (Fig.2). Then, in relation (2), the coefficient $\beta = -\mu_B^2$ (3) and the characteristic distance $R_0 = \sqrt{3} \cdot \mu_B / e$ (4) are determined through the known charge of the electron $e_1 = e_2 = e$ and the Bohr magneton μ_B [5]. Note that such a distance $R_0 \approx 3.5 \cdot 10^{-13} \text{m}$ is many times smaller than the characteristic sizes of atoms $\sim 10^{-9} - 10^{-10} \text{m}$, but is much larger than the effective sizes of atomic nuclei $\sim 10^{-14} - 10^{-15} \text{m}$. It should be noted that the size of a free electron is negligibly small, because its possible radius does not exceed 10^{-22}m , according to recent

studies [6]. Thus, on our theoretical model, electrons can be considered as point particles even at distances $R \ll R_0 \approx 3.5 \cdot 10^{-13} \text{m}$. Obviously, under high vacuum conditions, it is practically impossible to bring two electrons close together at such a small distance R_0 due to their Coulomb repulsion. However, the existence of paired electrons with oppositely directed spins in atoms is known. It is precisely these systems of electrons, connected through their intrinsic magnetic moments, that form the inner closed shells of atoms [3]. Therefore, under certain ionization conditions of atoms, such paired electrons can end up in free space.

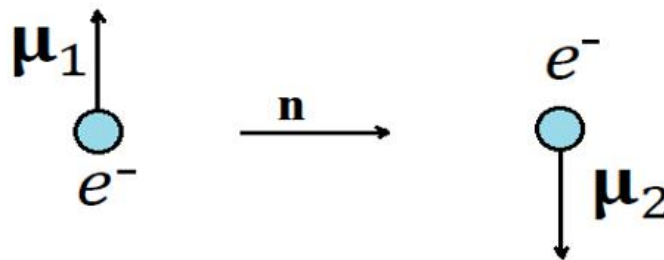


Fig. 2. The system of 2 electrons with oppositely directed intrinsic magnetic moments $\mu_1 = -\mu_2$.

4. MULTIPLE-PARTICLE SYSTEMS

Now let us consider, for example, a system consisting of three identical particles with the charge $e_1 = e_2 = e_3 = q$, which are located at equal distances from each other. It is assumed that the intrinsic

magnetic moments of these particles $\mu_1 = \mu_2 = -\mu_3$ are orthogonal to the plane passing through these point particles, with the vectors μ_1 and μ_2 oriented in the same direction, and μ_3 in the opposite direction (Fig.3).

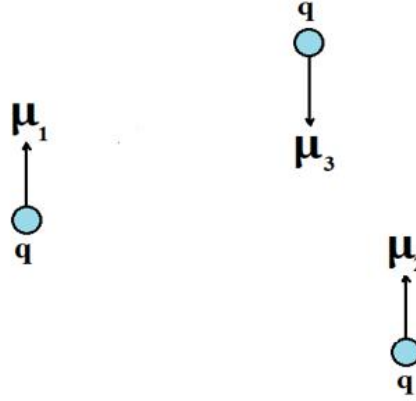


Fig. 3. The system of three equally spaced particles with the same charge q and intrinsic magnetic moments $\mu_1 = \mu_2 = -\mu_3$.

Then the potential energy U (1) of such a system has the form:

$$U = \frac{3q^2}{R} - \frac{\mu_1^2}{R^3}, \quad (5)$$

where $R = R_{12} = R_{13} = R_{23}$. Note that the dependence $U(R)$ (5) is also qualitatively described by the Fig. 1. According to (5), at a sufficiently small distance R , the magnetic attraction between such particles will be stronger than their Coulomb repulsion. At the same time, in contrast to the previous case with two particles, the system of three particles under consideration has the non-zero resulting magnetic moment $\mathbf{M} = \mu_1 + \mu_2 + \mu_3 = \mu_1$.

Similarly, based on general formula (1), one can imagine many other spatial configurations of varying numbers of like-charged particles with specific orientations of their intrinsic magnetic moments. At sufficiently small distances between particles, the forces of their magnetic attraction will be stronger than their Coulomb repulsion. It is important to note that as these particles approach each other further, their potential energy will decrease (Fig. 1), leading to their possible fusion.

5. ON THE STRUCTURE OF A FREE ELECTRON

A free electron is currently considered an indivisible, point-like elementary particle, and its possible constituent parts are still unknown [5,6]. However, based on the above analysis, it is possible to understand the previously unexplained reason for the extremely small (effectively point-like) size of a free electron and its resistance to decay due to the electron's self-generated Coulomb repulsion forces. Indeed, the electron's intrinsic magnetic moment is clearly

determined by its internal magnetic structure. This structure is formed in such a way that the potential energy of a stable free electron is minimized. This can only occur due to magnetic attraction forces within the electron. According to the above analysis, such attraction is much stronger than Coulomb repulsion at sufficiently small distances, characteristic, in particular, for the electron's size. Thus, this magnetic attraction between possible fragments of a free electron not only prevents the electron from decaying into such fragments but also constricts its volume to an extremely small value, the lower limit of which has not yet been established.

It is important to note that this result also explains the well-known paradox of the infinitely large self-energy of the electron [7]. Indeed, such energy was previously associated with the electrostatic component $\sim e^2/R$, which tends to infinity for a point electron with the charge e and effective radius $R \rightarrow 0$. In fact, due to the internal forces of magnetic attraction, the self-energy of a free electron decreases at $R \rightarrow 0$, as shown schematically in Fig. 1, up to the value determined, apparently, by the rest energy of the electron $mc^2 \approx 0.511$ MeV [5].

6. CONCLUSIONS

Theoretical studies of the interaction of charged particles, having intrinsic magnetic moments, are typically conducted within the framework of quantum mechanics [3,4]. Specifically, when considering systems of electrons, their spin-spin interaction is assumed to be weak compared to their Coulomb repulsion and is calculated using perturbation theory. In this paper, using the relations of classical electrodynamics, we analyze the opposite situation, where the interaction between the intrinsic magnetic moments of charged particles in vacuum is dominant.

Based on this, we demonstrate the possibility of fusion of like-charged particles when the distances between them are smaller than certain critical values. Thus, in particular, the formation of paired electrons in vacuum is shown. Furthermore, it is established that the integrity and extremely small (practically point-like)

size of a free electron is due to the presence of its intrinsic magnetic moment. This result also explains the well-known paradox of the infinitely large self-energy of the electron [7].

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