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On the Structure of the Electron

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Abstract

Here we continue the discussion of the nature of elementary particles based on the theory of electrodynamics (generalized Maxwell equations [1]). As is noted in [1], such a theory should exist because photons partake in a variety of reactions in which they turn elementary particles into particles of other forms while having the property of being a quantum of an electromagnetic field. Unlike the widely accepted theory of point particles, we propose that particles are not "elementary" particles (*i.e.* without structure) but rather complex formations. The attractive feature of our proposed theory is that it only operates on two quantities: the electric field $\boldsymbol{E}$ and the magnetic field $\boldsymbol{H}$. The multitude of particles is determined via their configuration, analogous to waves in waveguides [2]. Such a comparison is naturally intuitive and purely qualitative. We give an approximate solution to the static field of the electron and we show that only over a large distance from the center of the particle the field exhibits the character of being purely electric, spherically symmetric, and conforming to Coulomb's law. However, close to the center it does not exhibit the same behavior and the static magnetic field can even surpass the electric field in magnitude.

Subject Areas

Modern Physics, Particle Physics

Keywords

Internal Structure of the Electron, Static Electric Field, Static Magnetic Field, Generalized Maxwell Equations

1. Introduction

To define the internal structure of elementary particles using the generalized theory of the Maxwell equations [1] it is necessary to solve a system of nonlinear partial differential equations, which is of course a difficult problem. Separating the field into its static and dynamics components [1] simplifies the problem by noting that the static component does not depend on the dynamic one. In the following we will only look at the particle's static field.

In [1] it is shown that if we assume the model that a particle has a spherically symmetric electric field, then the approximate solution far from the center tends asymptotically to Coulomb's law as the radius increases, while near the center the two don't agree. In the following we will solve the problem of determining the magnetic field. Even in this simple case the magnetic field is not spherically symmetric. Far from the center it decays faster than the electric field and the full field becomes essentially purely electric satisfying Coulomb's law. However, near the center the magnetic field increases and can even become bigger than the electric field; in this case the approximate solutions are not sufficient.

This way, the structure of the static electromagnetic field of the electron is complicated (and multilayered). There are at least two radial boundaries: $\overline{r}$ and $\hat{r}$, near which the field changes its character. For $r > \overline{r}$, the field is practically purely electric and satisfies Coulomb's law, while for $r < \overline{r}, \hat{r}$, the magnetic field increases and the approximate solution that we make use of becomes problematic.

Future research will have to clarify the internal structure of the electron using a more rigorous solution to the static equations and the dynamic equations [1].

2. Basic Relations

In [1] they introduce a system of nonlinear partial differential equations that are a generalization of Maxwell equations of electrodynamics with which it seems possible to describe the internal structure of elementary particles. To our point of view, the attractive feature of this theory is that it only makes use of only two vector functions: the electric field $\boldsymbol{E}(\boldsymbol{r},t)$ and the magnetic field $\boldsymbol{H}(\boldsymbol{r},t)$. The multitude of particles is then defined by their configurations.

The system of four equations for $\boldsymbol{E}$ and $\boldsymbol{H}$ can be written in a more compact and elegant form consisting of only two equations by introducing a new quantity—the complex vector $\boldsymbol{\Psi}(\boldsymbol{r},t)$ given by

$$\boldsymbol{\Psi}(\boldsymbol{r},t) = \boldsymbol{E}(\boldsymbol{r},t) + i\boldsymbol{H}(\boldsymbol{r},t).$$

We define a solution $\boldsymbol{\Psi}$ of the form

$$\boldsymbol{\Psi}(\boldsymbol{r},t) = \boldsymbol{\Psi}_0(\boldsymbol{r}) + \tilde{\boldsymbol{\Psi}}(\boldsymbol{r})\mathrm{e}^{-i\omega t},$$

which resembles the function $\boldsymbol{\Psi}$ in Schrödinger's equation:

$$\Psi(\boldsymbol{r},t) = \Psi(\boldsymbol{r})\mathrm{e}^{-i\omega t},$$

but with the significant difference that in our case the solution is not a scalar, but avector function and has a static component (*i.e.* independent of time) which is determined by the system of equations [1]:

$$\begin{aligned}
&\operatorname{rot} \boldsymbol{H}_0 = \beta \operatorname{grad}\left(\boldsymbol{E}_0^2 - \boldsymbol{H}_0^2\right), \\
&\operatorname{rot} \boldsymbol{E}_0 = -2\beta \operatorname{grad}\left(\boldsymbol{E}_0 \boldsymbol{H}_0\right), \\
&\operatorname{div} \boldsymbol{E}_0 = \alpha\left(\boldsymbol{E}_0^2 - \boldsymbol{H}_0^2\right), \\
&\operatorname{div} \boldsymbol{H}_0 = 2\alpha \boldsymbol{E}_0 \boldsymbol{H}_0.
\end{aligned} \tag{1}$$

From (1) it follows that unlike the Maxwell equations the electric field $\boldsymbol{E}_0$ and the magnetic field $\boldsymbol{H}_0$ cannot exist without the other. There exists a magnetic charge (fourth equation) and a magnetic current (second equation) that are defined by the pseudoscalar $\boldsymbol{E}_0\boldsymbol{H}_0$ [1]. It is interesting to note that the magnetic monopole (a hypothetical particle) being a magnetic charge and having only one magnetic pole (analogous to an electric charge) was first studied by Dirac but not yet observed experimentally. Considering that the magnetic charge has not been observed experimentally, we can assume that we can set $\boldsymbol{E}_0\boldsymbol{H}_0 = 0$ (*i.e.* $\boldsymbol{E}_0 \perp \boldsymbol{H}_0$). In this case (1) simplifies to

$$\begin{aligned}
&\operatorname{rot}\boldsymbol{H}_0 = \beta \operatorname{grad}\left(\boldsymbol{E}_0^2 - \boldsymbol{H}_0^2\right),\\
&\operatorname{rot}\boldsymbol{E}_0 = 0,\\
&\operatorname{div}\boldsymbol{E}_0 = \alpha\left(\boldsymbol{E}_0^2 - \boldsymbol{H}_0^2\right),\\
&\operatorname{div}\boldsymbol{H}_0 = 0.
\end{aligned} \tag{2}$$

Assuming that the following relation holds:

$$\frac{\boldsymbol{H}_0^2}{\boldsymbol{E}_0^2} \ll 1, \tag{3}$$

the problem simplifies greatly and Equations (2) take the form

$$\begin{aligned}
&\operatorname{rot}\boldsymbol{H}_0 = \beta \operatorname{grad}\boldsymbol{E}_0^2,\\
&\operatorname{rot}\boldsymbol{E}_0 = 0,\\
&\operatorname{div}\boldsymbol{E}_0 = \alpha\boldsymbol{E}_0^2,\\
&\operatorname{div}\boldsymbol{H}_0 = 0.
\end{aligned} \tag{2'}$$

Considering the second equation in (2') we have that

$$\boldsymbol{E}_0 = \operatorname{grad}\varphi.$$

Furthermore, with the help of Hamilton's operator ∇ and remembering that the Laplacian $\Delta = \nabla^2$ we get that the third equation takes the elegant form

$$\nabla^2\varphi = \alpha\left(\nabla\varphi\right)^2. \tag{4}$$

In the general case the potential φ depends on all three spatial coordinates, for that reason the vector $\boldsymbol{E}_0$ has all three components. In the spherically symmetric case: $\varphi(\boldsymbol{r}) = \varphi(r)$, the field only has one radial component $E_{0r}(r)$, depending only on the radius *r*, and thus the third equation in (2') for E_{0r} takes the form

$$\frac{\mathrm{d}E_{0r}(r)}{\mathrm{d}r} + \frac{2}{r}E_{0r}(r) = \alpha E_{0r}^2(r),$$

the solution of which is given in [1]:

$$E_{0r} = \left(\alpha r + q^{-1}r^2\right)^{-1}, \tag{5}$$

where q is the particle's charge.

For $r \gg 1$, far from the particle's center,

$$E_{0r} = \frac{q}{r^2}, \tag{5'}$$

which agrees with Coulomb's law. But close to the center, the field differs from Coulomb's law:

$$E_{0r} \sim \frac{1}{\alpha r}, \tag{5''}$$

and the boundary between these two limit cases is approximately given by (5) assuming that

$$\alpha r = q^{-1} r^2,$$

or $\bar{r} = \alpha q$. Using the radius of the electron r_0 [1], we have that

$$\bar{r} = 0.1 r_0.$$

This way, for $r > \bar{r}$, E_{0r} tends to Coulomb's law, while for $r < \bar{r}$ that is not the case.

We now define the static magnetic field of the electron using the first equation in (2') and plugging in on the right-hand side the value $\boldsymbol{E}_0 \to E_{0r}$ using (5). We get

$$\mathrm{rot}_r \boldsymbol{H}_0 = \beta \frac{\mathrm{d}}{\mathrm{d}r} E_{0r}^2(r),$$

or

$$\frac{1}{r \sin\theta}\left[\frac{\partial H_{0\theta}}{\partial \varphi} - \frac{\partial}{\partial \theta}\left(H_{0\varphi} \sin\theta\right)\right] = \beta \frac{\mathrm{d}}{\mathrm{d}r}\left(\alpha r + q^{-1} r^2\right)^{-2}.$$

Assuming that the field $\boldsymbol{H}_0$ does not depend on the coordinate φ, we have that

$$-\frac{1}{r \sin\theta} \frac{\partial}{\partial \theta}\left(H_{0\varphi} \sin\theta\right) = \beta \frac{\mathrm{d}}{\mathrm{d}r}\left(\alpha r + q^{-1} r^2\right)^{-2}.$$

Integrating this gives us

$$H_{0\varphi} = 2\beta \frac{\alpha + 2q^{-1} r}{\left(\alpha r + q^{-1} r^2\right)^3} \cot\theta. \tag{6}$$

For $r \gg 1$, far from the particle's center

$$H_{0\varphi} \to \frac{4\beta q^2}{r^5}.$$

Considering (5') we have that

$$\frac{H_{0\varphi}}{E_{0r}} \to \frac{4\beta q}{r^3} \to 0.$$

That is, at great distance from the center the electron's field is essentially purely electric.

Close to the particle's center ($r \ll 1$)

$$H_{0\varphi} \to \frac{2\beta}{\alpha^2 r^3},$$

and considering (5'') we get that

$$\frac{H_{0\varphi}}{E_{0r}} \to \frac{2\beta}{\alpha r^2} \to \infty,$$

that is the assumption (3) does not hold, and thus in this case all of the above results are not valid anymore. We analyze the boundary of the permissible region in which hypothesis (3) holds:

$$\frac{H_{0\varphi}}{E_{0r}} = 1,\ \frac{2\beta}{\alpha r^2} = 1,\ \hat{r} = \sqrt{\frac{2\beta}{\alpha}}.$$

For $\hat{r} > 1$, the obtained results can be with certain measure of certainty be considered valid, but not for $\hat{r} < 1$!

For the results obtained above we can come to the following conclusions:

The structure of the electron's static electromagnetic field is very complicated (and multilayered) and has at least two boundaries in its radius: $\overline{r}$ and $\hat{r}$ which when approached the field changes its structure.

The electron's field is asymptotically spherically symmetric and electrostatic only at great distances from the particle's center.

The magnetic static field grows close to the particle's center and can even become bigger than the electric field.

This way we can recall how V. I. Lenin in his work [3] said way back in 1909 that "The electron is as inexhaustible as the atom…"

3. Note

Analyzing the unusual solutions to the static Equations (1) leads to an interesting concept. Assuming $\boldsymbol{E}_0 \perp \boldsymbol{H}_0$ or $\boldsymbol{E}_0\boldsymbol{H}_0 = 0$ and $\boldsymbol{E}_0^2 = \boldsymbol{H}_0^2$ ($\Psi_0^2 = 0$), from (1) we get

$$\boldsymbol{E}_0 = \text{const},\ \boldsymbol{H}_0 = \text{const}.$$

That is, the static field satisfying the above conditions fills up all of space. It's possible that this is the so called "ether". Any local fluctuation in time brings about the appearance a variable electromagnetic field that is the creation of a particle. The decay of the fluctuation—to the disappearance of a particle.

This consideration in a certain sense reminds us of Dirac's 1930 proposal that vacuum represents a space in which at every point there exists an infinite number of electrons of negative energy that forms a background from which it's possible to calculate all physical quantities [4].

Conflicts of Interest

The author declares no conflicts of interest.

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