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Calculation of the magnetic field inside the electron

Mesude Saglam[a,*], Gokhan Sahin[b], Hanasli Gur[c]

[a] Department of Physics, Faculty of Science University of Ankara, 06100 Ankara, Turkey
[b] Department of Electrical and Computer Engineering, Miami University, Oxford, OH, USA
[c] Ankara University, Department of Engineering in Physics, 06100 Tandogan, Ankara, Turkey

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ABSTRACT

The aim of this study is to investigate the magnetic field inside a free electron due to its spin, even in the absence of any field. Earlier we had found that the flux contribution of electron spin is in fact $\pm\Phi_0/2$ depending on the spin up and down cases. Therefore, because of its spin an electron carries a flux quantum of $\Phi_0/2 = 2.07 \times 10^{-7}\,\mathrm{G\,cm^2}$. We find that the magnetic field inside the electron is about $B = 8.3 \times 10^{13}$ T which is about 8.3×10^{11} times bigger than the highest magnetic field obtained in today's conditions. Therefore, at the moment the electron is still an unbreakable particle.

Introduction

Magnetic flux associated with electron spin was first calculated by Saglam and Boyacioglu [1] using a semiclassical model: The magnetic flux quantum of electron spin was found to be $\Phi_e^{(s)} = \pm\frac{hc}{2e}$ which has a magnitude of $2.07 \times 10^{-7}\,\mathrm{G\,cm^2}$. Wan and Saglam [2] calculated the intrinsic magnetic flux associated with the electron's orbital and spin motions. They obtained two basic magnetic flux quanta: the electron orbital magnetic flux quantum $\Phi_e^{(0)} = \frac{hc}{e}$ and the electron spin magnetic flux quantum $\Phi_e^{(s)} = \pm\frac{hc}{2e}$. Saglam et al [3] found the same results above by a full quantum mechanical solution of the Dirac equation for an electron moving in a homogeneous magnetic field. It was measured by Deaver and Fairbank [4] as well. In the present case since we consider only a free electron we will have the term $\Phi_e^{(s)} = \pm\frac{hc}{2e}$. Our aim is to find the order of magnitude of the magnetic field inside an electron.

Formalism

Following Saglam and Boyacıoglu [1], we assume that the spin angular momentum of the electron is produced by the fictitious point charge $(-e)$ rotating in a circular orbit with the angular frequency ω_s and the radius R in the x-y plane. As it is shown in [1], as far as the magnetic flux is concerned the radius is a phenomenal concept whose detailed calculation in terms of electron radius is not important here.

Spin magnetic moment of a free electron is given by

$$\boldsymbol{\mu} = g\mu_B \mathbf{S} \tag{1-1}$$

where $\hbar\mathbf{S}$ is the spin angular momentum of the electron. When we introduce the magnetic field $\boldsymbol{B} = B\boldsymbol{z}$, the z component of the magnetic moments becomes:

$$\mu_z = \pm\mu_B = \pm\frac{e\hbar}{2mc}. \tag{1-2}$$

When we place a spinning electron in an external magnetic field, B, the field will not change the electron's intrinsic angular velocity ω_s (because $\omega_s \gg \omega_c = eB/mc$). However, it will apply a torque of $\boldsymbol{\mu} \times \boldsymbol{B}$ which becomes zero when the spin is either parallel or anti-parallel to the magnetic field. In this case the z-component of this magnetic moment for a spin-down electron will be

$$\mu_z = -\frac{IA}{c} = \frac{e\omega_s A}{2\pi c}, \tag{1-3}$$

where $A = \pi R^2$ is the area of the above mentioned circular loop. If we compare Eqs. (1-2) and (1-3) we find:

$$A = -\frac{h}{2m\omega_s} \tag{1-4}$$

Now we proceed to calculate the flux for a spin–down electron during the cyclotron period T_c.

It is worth noting that during the cyclotron period T_c the electron will complete ω_s/ω_c turns about itself. So, the total flux during the cyclotron period will be:

$$\phi(\downarrow) = \frac{\omega_s}{\omega_c} AB. \tag{1-5}$$

Substitution of Eq. (1-4) and $\omega_c = eB/mc$ in Eq. (1-5) gives

* Corresponding author.
E-mail address: saglam@science.ankara.edu.tr (M. Saglam).

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$$\phi(\downarrow) = \frac{hc}{2e} = \frac{\phi_o}{2} \tag{1-6}$$

Similarly, the flux for the spin-up electron will take the form:

$$\phi(\uparrow) = \frac{hc}{2e} = -\frac{\phi_o}{2} \tag{1-7}$$

We note that the results we obtained in Eqs. (1-6) and (1-7) are independent of the magnetic field. Therefore, the smallest B will do as far as we choose the z-direction.

We next aim to compute the intrinsic magnetic field $B_z(in)$ inside electron. From Eq. (1-6) the magnetic flux associated with this inner field will be:

$$\pi R^2 B_z(in) = 2 \times 10^{-7}\,\mathrm{G\,cm^2} \tag{1-8}$$

Taking $R = 2.82 \times 10^{-13}$ cm, [5] for a spin-down electron one finds:

$$B_z(in) = 8.3 \times 10^{13}\ \mathrm{T} \tag{1-9}$$

To provide perspective, the magnetic field inside the electron is about 8.3×10^{11} times bigger than the highest magnetic field obtained in today's laboratories [6,7] and 10^3 times bigger than that in neutron stars (magnetars) [8,9].

Conclusion

We calculate that the magnetic field inside an electron is about $B = 8.3 \times 10^{13}$ T. This is about 8.3×10^{11} times bigger than the highest obtainable magnetic field in today's conditions. Therefore, the electron is an unbreakable fundamental particle.

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