Electron Toroidal Moment

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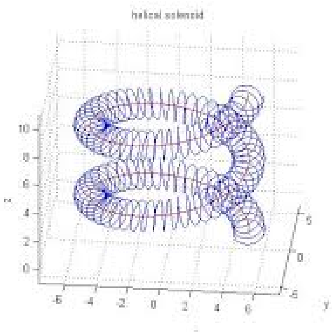
Abstract

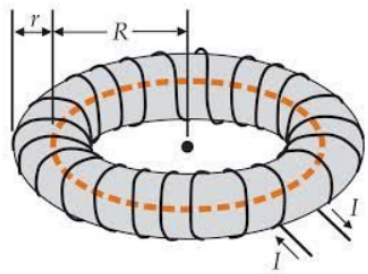
A semiclassical model of the electron is proposed. This model is based on the Ring Electron Model of Parson and the Zitterbewegung Electron Model of Hestenes. This "Solenoid Helical Electron Model" is described in [1] and [2]. This model necessarily implies a toroidal moment for the electron. This toroidal moment is a direct consequence of this model and it is not predicted by Quantum Mechanics. This prediction can serve as experimental evidence to validate or discard the proposed model.

1 Introduction

According to the statistical interpretation of Einstein, Quantum Mechanics (QM) describes the behavior of ensembles of particulates and is not applicable to individual particles. Therefore, QM is not a complete theory and it is necessary to create a new theory applicable to individual particles ("hidden variables theory"). This new theory should be deterministic ("God does not play dice") and each particle should have always a defined path.

Assuming the statistical interpretation of the QM, we proposed a semiclassical model of the electron called "Helical Electron Model"[1]. This model is based on both Ring Electron Model of Parson and the Zitterbewegung Electron Model of Hestenes. Later, In order to obtain the g-factor of the electron, we proposed a refinement of the model called "Helical Solenoid Electron Model"[2].





According this model, the electron is an infinitesimal electric charge that moves always at the speed of light along a path with a solenoid helical geometry and with an angular momentum equal to the reduced Planck constant. For an electron at rest, the geometry of the electron becomes of a toroidal solenoid. This Helical Solenoid Model is valid for any other subatomic particle, such as proton or neutron.

2 Summary of the Helical Solenoid Electron Model

The electron trajectory as a helical solenoid can be described by the following equation:

$$x(t) = (R + rcosNwt)coswt$$

$$y(t) = (R + rcosNwt)sinwt$$

$$z(t) = rsinNwt + vt$$

Where "v" is the velocity of the center of the torus (which coincides with the center of mass of the electron). We postulate that the tangential velocity of the particle has to be always equal to the speed of light, and we obtain the fundamental equation of the electron in this model.

$$|r'(t)|^2 = c^2 = (Rw)^2 + (rNw)^2 + v^2 + (2Rrw^2 + r^2w^2cosNwt + 2vrNw)cosNwt$$

From the Helical Solenoid equation, the g-factor of the electron is obtained as a result of its own geometry (with $rN << R$)

$$g.factor = \sqrt{1 + (rN/R)^2}$$

And the velocity of rotation depends only on the g-factor and the Lorentz factor

$$v_r = c/g\gamma$$

Applying the following relations, we obtain a value of the g-factor of 1,0011607.

$$\frac{rN}{R} = \sqrt{\frac{\alpha}{\pi}}$$

$$g = \sqrt{1 + \alpha/\pi}$$

We also postulate that the angular momentum of the particle has to be always equal to the reduced Planck constant. This gives us a value of electron radius equal to the reduced compton wavelength.

$$L = mRv_r = \hbar$$

$$L = m'R'v_r = (\gamma m)(gR)(c/g\gamma) = \hbar$$

$$L = mRc = \hbar$$

$$R = \frac{\hbar}{mc} = \lambda\!\!\!^{-}_c$$

In this model, the rotation period of the electric charge and the frequency of the electron are:

$$T_e = \frac{2\pi R}{v_r} = \frac{h}{mc}\frac{g\gamma}{c} = \gamma g\frac{h}{mc^2}$$

$$f_e = \frac{1}{T_e} = \frac{mc^2}{\gamma gh}$$

We calculate the wavelength of the electron like the the distance between two complete turns of the helix (this value is also called "Helical Pitch").

$$\lambda_e f_e = v$$

$$\lambda_e = \frac{v}{f_e} = g\gamma\beta\lambda_c$$

The movement of the electric charge causes an electrical current. The electron voltage is equal to the energy divide by the unit of charge. The voltage is caused by the magnetic flux divided by the unit of time.

$$I = ef_e$$

$$V = E/e = hf_e/e$$

$$V = \phi_e / T_e$$

Applying Ohm's law, we obtain a fixed value for the impedance of the electron equal to the value of the "Quantum Hall Resistance". On the other hand, the value of the magnetic flux of the electron is also fixed and equal to the "Magnetic Flux Quantum".

$$R = \frac{V_e}{I_e} = \frac{hf_e/e}{ef_e} = \frac{h}{e^2}$$

$$\phi_e = V_e T_e = \frac{hf_e}{e}\frac{1}{f_e} = \frac{h}{e}$$

Both the electrical current and the voltage of the electron are frequency dependent. This means that the electron behaves as an LC Quantum Circuit with a Capacitance (C) and Self Inductance (L):

$$L_e = \frac{\phi_e}{I_e} = \frac{h}{e^2 f_e}$$

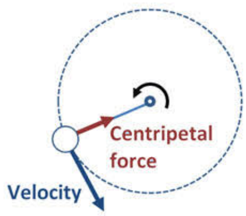
$$C_e = \frac{e}{V_e} = \frac{e^2}{hf_e}$$

$$Z_e = \sqrt{\frac{L_e}{C_e}} = \frac{h}{e^2}$$

$$f_e = \frac{1}{\sqrt{L_e C_e}} = \frac{mc^2}{g\gamma h} = f_e$$

3 Zitter Force and Schwinger Limits

The Helical Electron Model implies the existence of a centripetal force that compensates the centrifugal force of the electron orbiting around its center of mass. David Hestenes[3] called this force "Zitter Force". In the case of the electron this force must be equal to 0.212 N.



$$F = m\frac{v_r^2}{R} = \frac{m^2c^3}{\hbar} = 0.212N$$

Electromagnetic fields with a Lorentz force greater than the Zitter Force should cause instabilities in the geometry of the electron. The limits of these electric and magnetic fields are:

$$F = eE + evB$$

$$E = \frac{m^2c^3}{e\hbar} = 1.32x10^{18}V/m$$

$$B = \frac{m^2c^2}{e\hbar} = 4.41x10^9T$$

These values are the same that the "Schwinger limits" in quantum electrodynamics (QED). According to QED, above these values, the electromagnetic fields are expected to behave in a nonlinear way. These limits were proposed by Fritz Sauter in 1931[4] and subsequently discussed by Werner Heisenberg. However they are called Schwinger limits in honor of Julian Schwinger[5], which calculated the nonlinear QED corrections due to these limits. Interestingly, we obtained exactly these same values directly from the Helical Electron Model without using QED.

Experimentally, these levels have not yet achieved directly [6, 7], although current research suggests that values above these electromagnetic fields values will cause unexpected behavior not explained by the Standard Model of Particles Physics.

4 Helicity and Chirality

In 1956, an experiment based on the beta decay of the cobalt-60 nucleus showed a clear violation of parity conservation. In the early 1960s the parity symmetry breaking was used by Glashow, Salam and Weinberg to develop the electroweak model and unify the weak nuclear force with the electromagnetic force. The empirical observation that electroweak interactions act differently on right-handed fermions and left-handed fermions is one of the basic characteristics of this theory.

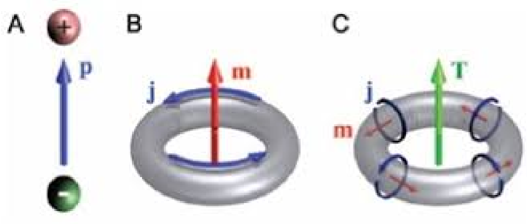
Chirality and helicity are essential properties of subatomic particles in the electroweak theory, however they are abstract concepts difficult to visualize. On the contrary, in the Helical Solenoid Electron Model, these concepts are evident and a direct consequence of its own geometry:

- The helicity is given by the helical translation motion of the electron (v$>$ 0), which can be left-handed or right-handed. The helicity of the electron is not an absolute value but it is relative to the speed of the observer.
- Chirality is given by the secondary helical rotational motion, which can also be left-handed or right-handed. The chirality of the electron is absolute since the tangential velocity of the electron is always equal to the speed of light and it is independent of the velocity of the observer.

5 Toroidal Moment

In 1957, Zel'dovich discussed parity violation of elementary particles and postulated that spin 1/2 Dirac particles must have an "anapole"[8]. In the late 1960s and early 1970s, Dubovik[9, 10] connected the quantum description of the anapole to classical electrodynamics by introducing the "polar toroidal multipole moments". The term "toroidal" stems from current distributions in the shape of a circular coil that were first shown to have a toroidal moment. Toroidal moments were not acknowledged outside the Soviet Union as being an important part of the multipole expansion until the 1990s. The toroid moments became known in western countries in the late 90's. Finally, in 1997, the Toroidal moment was measured experimentally in the nucleus of Cesium-133 and Ytterbium-174[11].

In an electrostatic field, all charge distributions and currents may be represented completely by a multipolar expansion using only electric and magnetic multipoles. Instead, in a multipolar expansion of an electrodynamic field new terms appear. These new terms correspond to a third family of multipoles: the toroid moments. The toroidal lower order term is the toroidal dipole moment. The toroidal moment can understood as the momentum generated by a distribution of magnetic moments. The simplest case is the toroidal moment generated by an electric current in a toroidal solenoid.



The toroidal moment is calculated from the following equation [9]:

$$T = \frac{1}{10}\int[(\mathbf{j}\cdot\mathbf{r})\mathbf{r} - 2r^2\mathbf{j}]dV$$

In the case of solenoid Toroidal, the toroidal moment can be calculated more directly as the B field inside the toroid by the volume of the torus[10].

$$B = \frac{\mu N I}{2\pi R}$$

$$\mu T = BsS = \frac{\mu N I}{2\pi R}(\pi r^2)(\pi R^2)$$

We obtain the toroidal moment equation, which coincides with the calculated in [12]:

$$T = \frac{N I (\pi r^2) R}{2}$$

In this Helical Solenoid Electron Model, an electron at rest is basically a superconductive toroidal solenoid. Therefore it must share all the electrical characteristics of a toroidal solenoid. In our model, the electric current, the Bohr magneton and g-factor are:

$$I = ef = e\frac{v_r}{2\pi R} = \frac{ec}{2\pi R g}$$

$$(\frac{Nr}{R})^2 = \frac{\alpha}{\pi}$$

$$\mu_B = \frac{ecR}{2}$$

Substituting and rearranging the terms:

$$T = \frac{ec}{4g}(\frac{R^2}{N})(\frac{Nr}{R})^2 = \frac{ecR}{2}\frac{1}{2g}(\frac{R}{N})(\frac{\alpha}{\pi})$$

We obtain the value of the Electron Toroidal Moment:

$$T = \mu_B \frac{R}{gN}(\frac{\alpha}{2\pi})$$

The theoretical Electron Toroidal Moment according this model is about $T \simeq 10^{-40} Am^3$. The theoretical toroidal moment value for the neutron and the proton should be one million times smaller. The existence of a toroidal moment for the electron (and for any other subatomic particle) is a direct consequence of this model and it may be validated experimentally. By contrast, the QM does not predict the existence of any toroidal moment.

6 Anapole Dark Matter

In 2013, Ho and Scherrer[13] hypothesized that the Dark Matter is formed by neutral subatomic particles. These particles of cold dark matter interact with ordinary matter only through an anapole electromagnetic moment, a kind of the toroidal magnetic moment described above. These particles would be Majorama fermions, and they can not have any other electromagnetic moment apart from the toroid moments. The model for these subatomic particles of dark matter is compatible with this Solenoid Helical Model.

7 Conclusion

This Toroidal Solenoid Electron model describe the electron as an infinitesimal electric charge moving at the speed of light along a helical path. From this semiclassical model, we can derive all the electron characteristics as the electron magnetic moment, the g-factor, its natural frequency, the value of Quantum Hall Resistance and the value of the Magnetic Flux Quantum. In this new work, we obtain other features such as the helicity, the chirality, the Schwinger limits and, especially, the Toroidal Moment of the electron. The experimental detection of the Toroidal Moment of the electron could be used to validate this model.

The toroidal moment of the electron is a direct consequence of Helical Solenoid Electron model and it is calculated qualitatively and quantitatively. This feature of the electron (and any other subatomic particle) is not contained in the standard model, but appears as a requirement to explain the violation of the parity symmetry of the subatomic particles. The existence of a toroidal moment has been experimentally verified in nuclei of heavy atoms and also serves as basis to explain the dark matter.

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