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Mass and Magnetic Flux Quanta in the Electron

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Abstract

In previous papers written by the author, the electron was modeled as having an outer shell of positive mass and an inner core of negative mass. The outer shell was assumed to have a mass much greater than the electron mass m_e, a mass equal to $\frac{3}{2\alpha}m_e$, where α is the fine structure constant. The outer shell mass assumption was based on the observation that the ratio of the electric and magnetic fields generated by the electron is remarkably close to the value of the fine structure constant. The author has also proposed a mass quantum of $\frac{1}{2\alpha}m_e$, deduced from the electron model. In this document, the mass quantum is used to justify the $\frac{3}{2\alpha}m_e$ outer shell mass assumption. The ratio of the electric to magnetic field is not used. Also in a previous paper, the author explained that if the outer shell has a mass of $\frac{3}{2\alpha}m_e$, then the electric charge on the outer shell must be $\frac{3}{2\alpha}e$, where e is the charge of the electron. This outer shell charge generates the magnetic field within the electron. It is shown from the electron model that the magnetic flux contained within the electron is exactly equal to the magnetic flux quantum observed for current in a superconductor. That fact is used to prove that the charge on the electron outer shell has a non-zero thickness. The thickness is determined by the g-factor and any other factor, such as an external magnetic field that adds magnetic flux internally to the electron. Also, the inductance of the electron has been calculated.

Keywords

Electron Model, Mass Quantum, Magnetic Flux Quantum, Electron Charge Shell, Superconductor, G-Factor, Electron Inductance

1. Introduction

In the author's previous paper [1], he proposed a mass quantum of $\frac{1}{2\alpha}m_e$, deduced from the electron model derivations. For example, the mass of the electron's outer shell was derived for a spin s of zero. When the spin angular momentum was increased to $s=\frac{1}{2}$, the outer shell mass was seen to increase by exactly $\frac{1}{2\alpha}m_e$. Since the publication of that paper, it has been brought to his attention that a study of the masses of about 200 elementary particles produced a common denominator equal to the mass quantum. That is, all of the 200 mass values are integral multiples of the mass quantum value, within reasonable tolerances [2]-[4]. That revelation inspired this author to use mass quantum as the justification for the outer shell mass assumption of $\frac{3}{2\alpha}m_e$, and to look for other possible outer shell masses that might also be multiples of the mass quantum. (The conclusion, as explained in the following, is that there are not any.) The outer shell mass assumption of $\frac{3}{2\alpha}m_e$ made in [5] was based on the observation that the ratio of the electron's electric and magnetic fields is remarkably close to the value of the fine structure constant. It will be shown that the mass quantum can provide an alternative justification for that assumption.

Stanford University scientists verified experimentally [6] that magnetic flux from current in a superconductor is indeed quantized. A theoretical derivation supporting that observation is presented in [7]. The magnetic moment of the electron derived from its model is used to calculate the magnetic field and flux contained within the electron. It will be shown that the net magnetic flux within the electron, after the g-factor is taken into account, exactly equals to the magnetic flux quantum. This result supports the electron model assumption that the charge of the outer shell is $\frac{3}{2\alpha}e$, and that the author's conclusion that the thickness of the charge on the outer shell is not zero, although very small.

The magnetic flux within the electron and the current due to the rotation of its charge are used to calculate the inductance of the electron.

Table 1 contains the constants used in the calculations in this document. Unless otherwise specified, all units are CGS.

Table 1. Table of constants.

Constant	Symbol	Value [cgs]
fine structure constant	α	$7.2973525693\times10^{-3}$
Planck's constant	h	6.62607015×10^{-27}
speed of light	c	2.99792458×10^{10}
electron mass	m_e	$9.1093837015\times10^{-28}$
electron radius	R	$2.817940325\times10^{-13}$
electron g-factor	g_e	2.00231930436256

2. Outer Shell Mass

The author has proposed that mass at the elementary particle level is quantized [1]. Scientists have correlated the mass values of about 200 elementary particles and found them to be integral multiples of a single value [2]-[4]. That value was found to equal the value of the proposed mass quantum $\frac{1}{2\alpha}m_e$. So elementary masses appear to be defined by $\frac{n}{2\alpha}m_e$, where $n \geq 1$ and n is the mass quantum integer. The electron structure model proposed by the author [1] [5] [8] assumes $n=3$ for the electron outer shell, but are other values of n possible? Other values are considered in the following for consistency with electron attributes. First, the integer $n=2$ is considered.

The spin angular momentum S predicted by the electron model is a function of the outer shell mass and thickness. It can be calculated from Equation (15) of [9].

$$S=\frac{nm_e cR}{2\alpha}\frac{\frac{1}{4}-\left(\frac{R_i}{R}\right)^5\int_0^1\sqrt{\frac{1-x^2}{1-\left(\frac{R_i}{R}\right)^2x^2}}x^3\mathrm{d}x}{\frac{1}{2}-\left(\frac{R_i}{R}\right)^3\int_0^1\sqrt{\frac{1-x^2}{1-\left(\frac{R_i}{R}\right)^2x^2}}x\mathrm{d}x} \tag{1}$$

where R is the outer radius and R_i is the inner radius of the outer shell mass. The spin angular momentum of the electron S_e is

$$S_e=\sqrt{s(s+1)}\frac{h}{2\pi}=9.133\times10^{-28} \tag{2}$$

where $s=\frac{1}{2}$. The solution of Equation (1) for $S=S_e$ is

$$\frac{R_i}{R}=0.9971, \tag{3}$$

calculated numerically using an online integral calculator. Therefore, for a mass quantum integer of $n=2$, an outer shell can be defined that has the correct spin angular momentum, although the shell is extremely thin. Next, the stability of such a shell is examined.

The pressures on the outer shell were derived in [1] for $n=3$, and are modified in the following for $n=2$. In particular, the variables that change are $\frac{R_i}{R}=0.9971$ and $\frac{q^-}{e}=\frac{n=2}{2\alpha}$. (It was explained in [8] that the outer shell charge q^- to electron charge ratio must be the same as the outer shell mass to electron mass ratio.)

Equation (28) of [1] is the mass density σ of the outer shell, and it becomes

$$\sigma=\frac{2e^2}{4\pi c^2\alpha R^4\left[1-\left(\frac{R_i}{R}\right)^3\right]}=1.0235\times10^{14} \tag{4}$$

Equation (29) of [1] is the centrifugal pressure on the outer shell at the electron equator, and it becomes

$$P_c = \sigma c^2 \left[-\frac{1}{3}\sqrt{\left(1-\left(\frac{R_i}{R}\right)^2\right)^3} + \sqrt{1-\left(\frac{R_i}{R}\right)^2} \right] \tag{5}$$
$$= \sigma c^2 \times 7.6010\times10^{-2} = 6.9920\times10^{33}$$

Equation (39) of [1] is the electrical pressure on the outer shell, and it becomes

$$\frac{\textit{electrical pressure } P_E}{\textit{surface tension pressure}} = \frac{\dfrac{eq^-}{4\pi R^4}}{\dfrac{\left(q^-\right)^2}{12\pi^2 R^4}} = 3\pi\frac{e}{q^-} = 3\pi\alpha = 0.068775927 \tag{6}$$

Equation (40) of [1] is the ratio of the outward pressures on the outer shell to the inward pressures, and it becomes

$$\frac{\textit{electrical } P_e + \textit{centrifugal } P_c}{\textit{surface tension pressure}} = 0.068775927 + \frac{6.9920\times10^{33}}{5.8013\times10^{33}} = 1.2740 \tag{7}$$

Since the ratio is greater than one, the outward pressure is not counterbalanced by the inward pressure, and tends to push the outer shell apart. Therefore, the mass quantum integer $n = 2$ is considered to be not viable.

Since the required spin angular momentum for $n = 2$ is just barely possible with the extremely thin outer shell, it certainly will not be possible for $n = 1$. Decreasing n in Equation (1) necessitates an increase in the charge shell inside radius R_i to maintain the correct value of momentum S. Increasing R_i to its maximum value R in Equation (1) yields a momentum of $S = 2.63643\times10^{-28}$, which is much lower than the required value of $S_e = 9.133\times10^{-28}$ from Equation (2). Therefore, the integer $n = 1$ is not viable.

The mass quantum integer $n = 4$ will be considered next. For $n = 4$, the spin angular momentum is expected to be large. Momentum can be reduced by increasing the outer shell thickness to where it fills the electron volume. For $R_i = 0$, Equation (1) yields a momentum of

$$S = \frac{4mcR}{2\alpha}\frac{\frac{1}{4}}{\frac{1}{2}} = \frac{mcR}{\alpha} = 1.055\times10^{-27} \tag{8}$$

Therefore, for mass quantum integers of $n = 4$ and greater, even if the outer shell were to have the maximum possibly thickness, the spin angular momentum would be too great. It appears, therefore, that $n = 3$ is the only viable mass quantum integer for the electron's outer shell. This conclusion has been determined using only integral values of the mass quantum, and not the observed value of the electron's magnetic moment.

3. Magnetic Flux

More information for the electron model can be gained by looking at the electron's internal magnetic flux.

Before using the outer shell charge to derive the magnetic moment and field, it is worth discussing the charge shell radius versus the radius of the outer shell mass m^+. Typically, the two radii are assumed to be the same. The outer shell charge radius was derived in [9] and expressed by Equation (12) of that paper. However, the radius of the outer shell mass could conceivably be different. If less than the charge radius, then the charge would float above the mass without contacting it. Intuitively, it would seem that such a charge cloud would collapse to the outer surface of the mass shell due to its magnetic surface pressure. On the other hand, if the outer shell mass radius were greater than the charge radius, then the centrifugal force of the portion of mass outside of the charge shell would not be counterbalanced by the magnetic surface pressure, and could be unstable. Therefore, the safest assumption seems to be that the charge and mass outer shells have the same radii. Section 4 of [9] arrives at the same conclusion, although for a different reason.

3.1. Magnetic Flux Quantum

This section considers a spinning sphere having attributes of the electron model. In [5], the electron's experimentally measured magnetic moment was used to justify the assumption of the value of the outer shell charge to electron charge ratio $\frac{q^-}{e}$. In the following, the magnetic moment M will be derived from the conclusion that the quantum mass integer for the outer shell must be $n = 3$ and the requirement that $\frac{q^-}{e} = \frac{m^+}{m}$. Therefore,

$$\frac{q^-}{e} = \frac{m^+}{m} = \frac{3}{2\alpha} \tag{9}$$

From Equation (11) of [9], the magnetic moment M for a spherical charge shell spinning at the speed of light is

$$M = \frac{1}{3} q^- R = \frac{eR}{2\alpha} \tag{10}$$

where R is the radius of the sphere. The magnetic field inside of the charge shell [10] is

$$B = \frac{2M}{R^3} \tag{11}$$

Merging Equations (10) and (11),

$$B = \frac{e}{\alpha R^2} \tag{12}$$

The electron charge e can be expressed as a function of the fine structure constant α.

$$e^2 = \frac{\alpha hc}{2\pi} \tag{13}$$

By combining Equations (12) and (13), the magnetic field B can then be expressed as

$$B = \frac{1}{\pi R^2}\frac{hc}{2e} \tag{14}$$

The magnetic flux inside the sphere crossing its equatorial plane can be derived by multiplying B by the area πR^2 of the equatorial plane inside the sphere. Therefore, the flux is

$$sphere.flux = \frac{hc}{2e} \tag{15}$$

Magnetic flux inside a superconducting current loop has been shown experimentally [6] and theoretically [7] to be quantized. The magnetic flux quantum is

$$magnetic.flux.quantum = \frac{hc}{2e} \tag{16}$$

According to BCS theory, superconductivity is the result of electron pairing at very low temperatures. Conceivably, the spinning charged sphere can be thought of as a superconductor in that its circular current due to its spin is persistent. This point of view is supported by comparing Equations (15) and (16). The magnetic flux within the sphere is exactly equal to one magnetic flux quantum.

$$sphere\ magnetic\ flux = magnetic\ flux\ quantum \tag{17}$$

3.2. G-Factor Adjustment

The model in the section above approximates an electron. A model of this type has been previously described in [11]. It differs from an electron model in that the g-factor anomaly is not included. That is, g_e has been assumed to be exactly equal to 2 instead of its slightly higher value. When the anomaly is added to that model, the predicted flux will not be equal to the magnetic flux quantum. The model described in [9] shows that the anomaly is the result of the electron charge shell having a non-zero thickness. If the charge shell thickness were to be actually zero, then the magnetic flux inside the electron would not be exactly equal to the flux quantum. The spherical charge internal flux calculation is adjusted below to include the electron g-factor anomaly.

The gyromagnetic ratio of the electron can be derived from the following equation [12], where $S_z = \pm\frac{1}{2}\frac{h}{2\pi}$.

$$\frac{M}{S_z} = \frac{e}{2m_e c} g_e \tag{18}$$

Replacing M in Equation (18) with Equation (10) and m_e with $m_e = \frac{e^2}{Rc^2}$ [13], the magnetic moment M becomes

$$M = g_e \frac{h}{8\pi}\frac{Rc}{e} \tag{19}$$

Using Equation (11), the magnetic field inside the electron becomes

$$B = \frac{g_e}{2}\frac{1}{\pi R^2}\frac{hc}{2e} \quad (20),$$

and the magnetic flux inside the electron would be

$$electron.magnetic.flux = B\pi R^2 = \frac{g_e}{2} magnetic.flux.quantum \quad (21)$$

If the electron charge shell were to be infinitely thin, then the magnetic flux inside the electron would be greater than the magnetic flux quantum by a factor of $\frac{g_e}{2}$. Equations (20) and (21) show that the magnetic flux within the electron is not dependent on the charge shell radius R. But, as derived below, it is dependent on the thickness of the charge shell.

The flux inside the electron can be reduced to exactly the magnetic flux quantum value by increasing the charge shell thickness from zero. The charge shell can be thought of as a multiplicity of nested, concentric charge subshells. As the radii of the subshells are decreased from R, the flux in the space between the outer-most subshell (radius R) and the inner-most subshell (radius R_{qi}) is decreased. At a radius r, the flux generated outside of subshells having radii less than r, and generated by those subshells, will be negative in the equatorial plane, and will partially cancel the flux generated by the subshells having radii greater than r. The canceling magnetic field $\Delta B\left(R \ge r > R_{qi}\right)$ [10] at a radius r between radii R and R_{qi} is

$$\Delta B\left(R \ge r > R_{qi}\right) = -\int_{R_{qi}}^{r} \frac{\mathrm{d}M}{r'^3}\mathrm{d}r' \quad (22)$$

where $\mathrm{d}M$ is the magnetic moment of each subshell, modified from [9] to include the g-factor.

$$\mathrm{d}M = \frac{2\pi g_e}{3R}\sigma_e r'^4 \mathrm{d}r' \quad (23)$$

where σ_e is the charge density.

$$\Delta B\left(R \ge r > R_{qi}\right) = -\frac{2\pi g_e}{3R}\sigma_e\left[\frac{1}{5r^3}\left(r^5 - R_{qi}^5\right)\right] \quad (24)$$

Thus, the total flux generated inside all of the charge subshells is reduced by

$$\Delta electron.magnetic.flux = \int_{R_{qi}}^{R} \Delta B\left(R \ge r > R_{qi}\right)\mathrm{d}A \quad (25)$$

where $\mathrm{d}A$ is the increment of area in the equatorial plane at radius r.

$$\mathrm{d}A = 2\pi r \mathrm{d}r \quad (26)$$

$$\Delta electron.magnetic.flux = -\frac{4\pi^2 g_e}{3R}\frac{1}{5}\sigma_e\frac{R^4}{4}\left[1 - 5\left(\frac{R_{qi}}{R}\right)^4 + 4\left(\frac{R_{qi}}{R}\right)^5\right] \quad (27)$$

where σ_e is the charge density [1].

$$\sigma_e = \frac{3q^-}{4\pi R^3\left(1-\left(\frac{R_{qi}}{R}\right)^3\right)} = \frac{9hc}{16\pi^2 eR^3\left(1-\left(\frac{R_{qi}}{R}\right)^3\right)} \quad (28)$$

$$\Delta electron.magnetic.flux = -\frac{3g_e hc}{80e\left(1-\left(\frac{R_{qi}}{R}\right)^3\right)}\left[1-5\left(\frac{R_{qi}}{R}\right)^4+4\left(\frac{R_{qi}}{R}\right)^5\right] \quad (29)$$

The value of the negative magnetic flux in the electron, $\Delta electron.magnetic.flux$, required to reduce the total magnetic flux to exactly the value of the magnetic flux quantum is

$$\left(\frac{g_e}{2}-1\right)magnetic.flux.quantum = \left(\frac{g_e}{2}-1\right)\frac{hc}{2e} \quad (30)$$

The thickness of the charge shell can be calculated by combining Equations (29) and (30) and solving numerically for R_{qi}.

$$\frac{3g_e hc}{80e\left(1-\left(\frac{R_{qi}}{R}\right)^3\right)}\left[1-5\left(\frac{R_{qi}}{R}\right)^4+4\left(\frac{R_{qi}}{R}\right)^5\right] = \left(\frac{g_e}{2}-1\right)\frac{hc}{2e} \quad (31)$$

$$\frac{R_{qi}}{R} = 0.9976780 \quad (32)$$

$$charge.shell.thickness = R - R_{qi} = 0.0023220R \quad (33)$$

The charge shell thickness calculated from the electron g-factor [9] is $0.0023175R$. The two calculated thicknesses are nearly identical. The thickness calculated from the magnetic flux quantum is less than 0.2% greater than the thickness calculated from the g-factor. Therefore, the magnetic flux quantum can be used to validate the non-zero thickness of the charge shell calculated in [9]. It also supports the conclusion that the electron mass quantum integer cannot be less than 3. Otherwise, the flux inside the electron would be a fraction of one magnetic flux quantum.

The above derivation shows that the charge shell thickness will adjust such as to cancel out any flux inside the electron that would cause the total flux to deviate from one magnetic flux quantum. For example, the shell thickness will change when an external magnetic field is applied to the electron.

4. Inductance

One of the definitions of inductance L is the change $\mathrm{d}\Phi$ in magnetic flux caused by a change $\mathrm{d}I$ in the current that is creating that flux, divided by that change [14].

$$L = \frac{\mathrm{d}\Phi}{c\mathrm{d}I} \quad (34)$$

The contribution to the magnetic flux and current by the outermost charge subshell is derived in the following. Using Equations (11) and (23), the magnetic moment of the subshell is

$$\mathrm{d}M(R) = \frac{2\pi g_e}{3}\sigma_e R^3 \mathrm{d}r \quad (35)$$

The magnetic field $\mathrm{d}B(R)$ inside the electron created by the subshell is

$$\mathrm{d}B(R) = \frac{2\mathrm{d}M}{R^3} = \frac{4\pi g_e}{3}\sigma_e \mathrm{d}r \tag{36}$$

The magnetic flux $\mathrm{d}\Phi$ crossing an equatorial plane area $A = \pi R^2$ inside the electron is

$$\mathrm{d}\Phi = \mathrm{d}B(R)A = \frac{4\pi^2 g_e}{3}\sigma_e R^2 \mathrm{d}r \tag{37}$$

The subshell current $\mathrm{d}I$ is the subshell charge $\mathrm{d}q^-$ times the frequency of rotation f.

$$\mathrm{d}I = \mathrm{d}q^- f = \sigma_e\left(4\pi R^2 \mathrm{d}r\right)\frac{c}{2\pi R} = 2c\sigma_e R\mathrm{d}r \tag{38}$$

Combining Equations (34), (37), and (38), the inductance L is

$$L(\mathrm{cgs}) = \frac{\mathrm{d}\Phi}{c\mathrm{d}I} = \frac{2g_e}{3}\left(\frac{\pi}{c}\right)^2 R \tag{39}$$

The inductance for MKS unit, using the conversion factor from [15] is

$$L(\mathrm{MKS}) = \frac{L(\mathrm{cgs})}{1.113\times10^{-12}} = 3.711393839\times10^{-21}\ \mathrm{H} \tag{40}$$

5. Summary

References are cited that provide experimental evidence supporting the author's proposed mass quantization deduced from his electron model. The mass quantum is $\frac{1}{2\alpha}$ times the mass of the electron, where α is the fine structure constant. The magnetic flux contained within the electron due to the spin of its charge is calculated to be equal to one magnetic flux quantum. The mass quantum and the magnetic flux quantum are each used to provide further evidence that the mass and charge of the outer shell of the electron are $\frac{3}{2\alpha}$ times the mass and charge of the electron, respectively, and that these values are unique in that they are consistent with other electron attributes. Furthermore, the magnetic flux quantum has been used to validate the conclusion previously reported by the author that the thickness of the electron charge outer shell is non-zero, although very small. The model shows that the charge shell thickness is such that the net magnetic flux inside the electron is always exactly equal to the magnetic flux quantum. The thickness is determined by factors such as the g-factor and external magnetic fields. Also, the inductance of the electron has been calculated.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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