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An Electron Model Based on the Fine Structure Constant

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Abstract

In previous publications, the author has proposed a model of the electron's internal structure, wherein a positively-charged negative mass outer shell and a negatively-charged positive mass central core are proposed to resolve the electron's charge and mass inconsistencies. That model is modified in this document by assuming the electron's radius is exactly equal to the classical electron radius. The attributes of the internal components of the electron's structure have been recalculated accordingly. The shape of the electron is also predicted, and found to be slightly aspherical on the order of an oblate ellipsoid. This shape is attributed to centrifugal force and compliant outer shell material. It is interesting to note that all of the electron's attributes, both external and internal, with the exception of mass and angular moment, are functions of the fine structure constant α, and can be calculated from just three additional constants: electron mass, Planck's constant, and speed of light. In particular, the ratios of the outer shell charge and mass to the electron charge and mass, respectively, are $\frac{3}{2\alpha}$. The ratios of the central core charge and mass to the electron charge and mass, respectively, are $1-\frac{3}{2\alpha}$. Attributes of the electron are compared with those of the muon. Charge and spin angular momentum are the same, while mass, magnetic moment, and radius appear to be related by the fine structure constant. The mass of the electron outer shell is nearly equal to the mass of the muon. The muon internal structure can be modeled exactly the same as for the electron, with exactly the same attribute relationships.

Keywords

Fine Structure Constant, Negative Mass, Electron Shape, Electron Structure, Electron Mass Inconsistency, Electron Charge Inconsistency, Muon

1. Introduction

The author has previously published a proposed model of the electron [1] which resolves large inconsistencies between the measured mass of the electron and the mass calculated from the spin angular momentum, and also between the measured charge of the electron and the charge derived from the magnetic dipole moment. The model introduces a positive charge and negative mass into the electron core and predicts the electron radius. This Dual-Charge Dual-Mass Model has been modified in this document by assuming that the radius exactly equals the classical electron radius. Interestingly, the consequence of this change is that the internal components of the electron become very simple functions of the fine structure constant. In fact, almost every attribute of the electron, both external and internal, is a function of the constant.

Many of the electron's attributes have been previously theoretically calculated, and are referenced herein to highlight their dependence on the fine structure constant. The intent of this document is to show that the components of the electron's internal structure also have very simple relations to the constant. The shape of the electron is also predicted as a function of the constant.

Values for the internal attributes of the electron can be calculated from the model using only four basic constants:

- Electron mass.
- Fine structure constant.
- Planck's constant.
- Speed of light.

The spin angular momentum S_Z is known from quantum theory. The theoretical expression for electron charge q is used to calculate the spin magnetic dipole moment M. The electron shape is then calculated from the ratio of the electron's electric and magnetic fields and the theoretical expression for the classical electron radius. Finally, the internal charges and masses are calculated for the electron and repeated for the muon.

It is interesting to compare the attributes of the electron with those of the muon. Charge and spin angular momentum are the same, while mass, magnetic moment, and radius appear to be related by the fine structure constant, as detailed below.

2. Derivations

Table 1 contains the base constants used in the model. They are the foundation

Table 1. Table of base constants.

constant	symbol	value [cgs]
fine structure constant	α	$7.2973525693 \times 10^{-3}$ [2]
Planck's constant	h	$6.62607015 \times 10^{-27}$ [3]
speed of light	c	$2.99792458 \times 10^{10}$ [4]
electron mass	m	$9.1093837015 \times 10^{-28}$ [5]

of the model. The only electron attribute that is a base constant is the measured value of the electron mass m. All other electron attributes are calculated as functions of these base constants. Their expressions and values derived from the calculations are listed in Table 2.

Unless otherwise specified, all units are CGS.

2.1. Magnetic Dipole Moment

The value of the electron spin angular momentum S is calculated from

$$S = \sqrt{s(s+1)}\frac{h}{2\pi} \text{ [6], where } s = \frac{1}{2}. \tag{1}$$

When placed in a magnetic field, the electron spin axis processes about the field vector at the Larmor precession frequency. The projection of the spin angular momentum vector of magnitude S on the Larmor precession axis is S_z.

The electron charge q is calculated from one of the expressions for the fine structure constant:

$$\alpha = \frac{q^2}{\left(\frac{h}{2\pi}\right)c} \text{ [2]}, \quad q = -\sqrt{\alpha\left(\frac{h}{2\pi}\right)c} \tag{2}$$

Table 2. Table of derived electron attributes.

Constant	Expression	Value [cgs]
spin angular momentum	$S = \sqrt{s(s+1)}\frac{h}{2\pi}, \quad s = \frac{1}{2}$	$9.132859842 \times 10^{-28}$
projection of S on Larmor precession axis	$S_z = s\frac{h}{2\pi}$ [6]	$5.272859088 \times 10^{-28}$
charge	$q = -\sqrt{\alpha\left(\frac{h}{2\pi}\right)c}$	$-4.803204713 \times 10^{-10}$
g-factor	$g_e = 2\left(1 + \sum_{i=1}^{\infty} C_i\left(\frac{\alpha}{\pi}\right)\right)$	2.002319304
magnetic dipole moment	$M = -\sqrt{\alpha\frac{h^3}{2^7\pi^3 m^2 c}}g_e$	$-9.284764698 \times 10^{-21}$ ($-9.2847647043 \times 10^{-21}$ [15])
classical electron radius	$R = \frac{q^2}{mc^2}$	$2.817940325 \times 10^{-13}$ ($2.8179403262 \times 10^{-13}$ [16])
shape eccentricity	$\frac{R}{r} = \sqrt{\frac{2M\alpha}{qR}}$	1.000579658
$\frac{\text{outer shell charge}}{\text{electron charge}} = \frac{\text{outer shell mass}}{\text{electron mass}}$	$\frac{q^-}{q} = \frac{m^+}{m} = \frac{3}{2\alpha}$	205.5539986
$\frac{\text{central core charge}}{\text{electron charge}} = \frac{\text{central core mass}}{\text{electron mass}}$	$\frac{q^+}{q} = \frac{m^-}{m} = 1 - \frac{3}{2\alpha}$	−204.5539986

For comparison with the NIST MKS value [7], the conversion to CGS is:

$$q = -1.602176634\times10^{-19}\left[\text{MKS}\right]\times\left(1/10\right)c = -4.803204713\times10^{-10}\ \text{emu}$$

The magnetic dipole moment of the electron *M* is derived from the gyromagnetic ratio of the electron γ_e, which is defined as

$$\gamma_e = \frac{M}{S_z} = \frac{q}{2mc}g_e \quad [8]. \tag{3}$$

The *g*-factor g_e has been calculated theoretically:

$$g_e = 2\left(1+a_e\right) \quad [9] \tag{4}$$

It can be expressed as an infinite number of fine structure constant terms:

$$a_e = \sum_{i=1}^{\infty} C_i\left(\frac{\alpha}{\pi}\right) \quad [10] \tag{5}$$

The condensed expression for *M* along with its value and the values of its factors are shown in **Table 2**.

2.2. Electron Shape

Insight into the shape of the electron can be gained by looking at the ratio of the electric field *E* at its surface to the magnetic field *B* at its center. For a spherical shape with classical electron radius *R*:

$$E = \frac{q}{r^2},\quad B = \frac{2M}{R^3}\quad [11],\quad R = \frac{q^2}{mc^2}\quad [12],\quad r = R \tag{6}$$

r = distance from center to a pole (intersection of the surface with the spin axis)

$$\frac{E}{B} = 0.998841691\alpha \tag{7}$$

The value of the $\frac{E}{B}$ ratio is remarkably close to the value of the fine structure constant, suggesting that the ratio is actually exactly equal to α and that the shape is actually slightly aspherical. *R* and *r* will have different values. While *r* is the distance from the center to a pole, *R* is assumed to be the radius at the equator. For $\frac{E}{B} = \alpha$,

$$\frac{R}{r} = \sqrt{\frac{2M\alpha}{qR}} = 1.000579658 \tag{8}$$

Therefore, the outer shell of the electron bulges slightly at the equator, probably caused by centrifugal force. A bulge as a function of centrifugal force indicates that the electron material is compliant, *i.e.*, not rigid.

The shape appears to be on the order of an oblate ellipsoid. The author calculated in [13] that the shape is a prolate spheroid. In the author's previous publications [1] [13] [14], a basic assumption was that the physical and electrical forces exactly balance out at the equator of the electron surface. The results were radii that were somewhat greater than the classical electron radius. The model presented in this document assumes the radius to be exactly equal to the classical electron radius. As a result, the forces will not balance out to zero at the equator. There will be a net outward force causing a bulge and requiring tensile strength of the electron material to hold the electron together.

2.3. Internal Attribute Values

The author's previous publications [1] [13] [14] assume an internal electron structure consisting of an outer shell and a very small central core. These two components have opposite charges and masses. It was shown that such a structure could be used to resolve the electron's charge and mass inconsistencies. The same structure is assumed in this document. The following is a calculation of the charge q^- on the outer shell.

Consider a charged spherical shell of compliant material and radius *r*. Slice the shell into many rings, each parallel to the equatorial plane with a charge q' and radius r'. The outer shell is comprised of this stack of rings. Spin the shell at a rate ω. The magnetic moment for each ring is

$$\frac{1}{2}\frac{1}{c}q'\omega r'^2 \quad [14], \quad \sum q' = q^- \tag{9}$$

For very small ω, the shape of the stack of rings is spherical. As ω is increased, each ring will expand. When ω has increased to a value such that the ring at the equator has a radius of *R*, the model assumes that the radius r' of each ring has expanded by a factor of $\left(\frac{R}{r}\right)$. Therefore, the magnetic moment of each ring has increased by $\left(\frac{R}{r}\right)^2$. Consequently, the magnetic moment of the outer shell has changed by a factor of $\left(\frac{R}{r}\right)^2$ as a result of the shape change.

For the equator of the electron spinning at close to the speed of light, the magnetic moment *M* assuming a spherical shape is expressed by

$$M = \frac{1}{3}q^- R. \tag{10}$$

For the aspherical shape calculated above,

$$M = \frac{1}{3}\left(\frac{R}{r}\right)^2 q^- R = \frac{1}{3}\frac{2M\alpha}{qR}\frac{q^-}{q}qR. \tag{11}$$

This solution to this equation is

$$\frac{q^-}{q} = \frac{3}{2\alpha}. \tag{12}$$

In the author's previous publications [1] [13] [14], the outer shell was given a positive charge to enable all forces at the equator to be balanced. Balance cannot be achieved with a negative charge because the charge would be greater than the central core positive charge, and the repulsive force on the outer shell would be greater than its attractive force to the core. However, for the model in this document, because the radius is the classical electron radius, the forces cannot be balanced. Consequently, the outer shell can have either a positive or negative charge. A negative charge was chosen so the corresponding mass of the outer shell is positive. There is some uncertainty as to how a negative mass shell would respond to a net inward force. The material would react opposite to the force, creating tensile stress to balance out the force. It seems like the material would react to its internal tensile stress by creating even more stress until it flies apart. By placing the negative mass at the center, any force on its material will be the outward electrical force from the outer shell charge, which will tend to compress the material.

For the negative mass central core to have a stable position at the center, the outer shell charge needs to be mobile. Normally, the central core will be positioned at exactly the center and the outer shell charge will be uniformly distributed across the shell surface. However, if the central core were to be perturbed off center, then there would be an attractive force on the core toward the nearest point on the outer shell. Since the core has negative mass, this force would actually move it back toward the center, counteracting the perturbation. Therefore, the position of the core will be stable.

The internal attributes are:

$q^+ \equiv$ charge of the central core.

$q^- \equiv$ charge of the outer shell.

$m^+ \equiv$ mass of the outer shell.

$m^- \equiv$ mass of the central core.

The relationships among the internal and external attributes are

$$\frac{q^-}{m^+} = \frac{q^+}{m^-} = \frac{q}{m} \quad [1] \tag{13}$$

The expressions and values for each are shown in **Table 2**.

3. Comparisons of Electron and Muon Attributes

The electron and muon are both leptons and share some common attributes. In particular, their charges and spin angular momentums are the same. Other muon attributes are quite different, but appear to be related to those of the electron via the fine structure constant α. In particular, those attributes are mass, magnetic moment and radius. The relationships are shown in **Table 3**. They are not exact functions of the fine structure constant, but they are quite close, and close enough to be of interest.

As can be seen in **Table 3**, the electron outer shell mass is very nearly equal to the muon mass, differing by less than 0.6%. When the muon decays, nearly all of its mass becomes the outer shell of the electron. The electron and muon magnetic moments and radii are related by the fine structure constant α, with a deviation of less than 0.6%. The muon radius was calculated using the same expression as for the classical electron radius. The electron mass was replaced with the muon mass.

Table 3. Muon constants and relations to electron attributes.

Constant	Expression	Value [cgs]
mass	m_μ	$1.883531627 \times 10^{-25}$ g [17]
$\frac{\text{muon mass}}{\text{electron mass}}$	$\frac{m_\mu}{m}$	206.768283
$\frac{\text{muon mass}}{\text{electron outer shell mass}}$	$\frac{m_\mu}{m^+} = \frac{2\alpha}{3}\frac{m_\mu}{m}$	1.005907374
magnetic moment	M_μ	$-4.49044830 \times 10^{-23}$ emu [18]
$\frac{\text{electron magnetic moment}}{\text{muon magnetic moment}}$	$\frac{M}{M_\mu}$	206.766988
$\text{moment ratio} \times \frac{\text{fine structure constant}}{3/2}$	$\frac{M}{M_\mu}\frac{2\alpha}{3}$	1.005901074
radius	$R_\mu = \frac{q^2}{m_\mu c^2}$	$1.36284941 \times 10^{-15}$ cm
$\frac{\text{electron radius}}{\text{muon radius}}$	$\frac{R}{R_\mu}$	206.768283
$\frac{\text{electron radius}}{\text{muon radius}} \times \frac{\text{fine structure constant}}{3/2}$	$\frac{R}{R_\mu}\frac{2\alpha}{3}$	1.005907374
shape eccentricity	$\frac{R_\mu}{r_\mu} = \sqrt{\frac{2M_\mu \alpha}{qR_\mu}}$	1.000582791
$\frac{\text{muon shape eccentricity}}{\text{electron shape eccentricity}}$	$\frac{R_\mu}{r_\mu} \div \frac{R}{r}$	1.000003131
$\frac{\text{outer shell charge}}{\text{muon charge}} = \frac{\text{outer shell mass}}{\text{muon mass}}$	$\frac{q_\mu^-}{q} = \frac{m_\mu^+}{m_\mu} = \frac{3}{2\alpha}$	205.5539986 (equal to the electron ratios)
$\frac{\text{central core charge}}{\text{muon charge}} = \frac{\text{central core mass}}{\text{muon mass}}$	$\frac{q_\mu^+}{q} = \frac{m_\mu^-}{m_\mu} = 1 - \frac{3}{2\alpha}$	−204.5539986 (equal to the electron ratios)

The muon internal structure can be modeled exactly the same as for the electron. The relationships between internal and external attributes are identical to those for the electron, as seen by comparing Table 2 and Table 3 entries.

If one were to assume that the muon and electron radii were the same, the above equations would show that all of the charge would reside on the outer surface, there would be no internal structure, and the shape would be a prolate ellipsoid.

4. Summary

The author has previously proposed the Dual Charge Dual Mass Model of the electron, which incorporates both positive and negative charges and masses to resolve the electron's charge and mass inconsistencies. That model has been modified in this document by assuming the electron radius is exactly equal to the theoretically calculated value of the classical electron radius. The resulting model shows that every attribute of the electron, both external and internal and except for mass, can be theoretically calculated from just four constants: fine structure constant, total mass, Planck's Constant, speed of light. Every attribute, except for mass and angular momentum, is a function of the fine structure constant. In particular, the internal positive and negative charge and mass components of the electron are very simple functions of the constant. All of the attributes calculated from the model agree with theoretical and experimentally measured values to within at least nine significant figures.

The model also predicts the shape of the electron. The shape is predicted to be aspherical, with a slight bulge at the equator due to centrifugal force from its spin. The model requires that the electron material be compliant, *i.e.*, not rigid. The shape is on the order of an oblate ellipsoid. The ratio of the major and minor axes has been calculated.

Attributes of the electron are compared with those of the muon. Charge and spin angular momentum are the same, while mass, magnetic moment, and radius appear to be related by the fine structure constant. The muon internal structure can be modeled exactly the same as for the electron. The relationships between internal and external attributes are identical to those for the electron.

Conflicts of Interest

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

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