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A Muon Model Derived from a Semi-Classical Electron Model

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Abstract

In the author's previous publications, a model for the electron was proposed, consisting of an outer shell, having positive mass and negative charge, and a central core, having negative mass and positive charge. In this publication, the muon is constructed by adding three mass quanta, each quantum having a mass of $\frac{1}{2\alpha}$ times the electron mass, to the electron mass. The resulting muon mass predicted by this model is only 0.1% less than the actual muon mass. This discrepancy is attributed to the omission of the mass of the muon neutrino, which is predicted to be 0.1095 MeV/c^2, consistent with the measured upper limit of 0.15 MeV/c^2. The muon radius is predicted to be 0.6% less than the electron radius. The muon mass is concentrated in a hollow shell, having an inside radius of 0.637167 times the muon radius. The muon charge is embedded in the outer surface of the mass shell. The predicted muon g-factor is exactly equal to the actual g-factor, to within the 9-significant figure precision of the calculations. The material embodying the mass of the muon appears to be the same as the material embodying the outer shell of the electron. This exact relationship enables the calculation of the radius of the central core negative mass. It can range from about 0.66 to 0.014 times the electron radius, depending on the core's speed of rotation. The volume density of the electron's central core negative mass ranges correspondingly from about 4 to 3×10^5 times greater than the density of the outer shell material. The radius of the central core positive charge is very much smaller than its mass radius, and is effectively zero. The electromagnetic pressure that helps to hold the electron together reverses polarity for the muon, and actually tends to push it apart. This could account for the tremendous difference in lifetimes between the two particles. The muon depends on the tensile strength of its material to hold it together.

Keywords

Muon Model, Muon Mass, Muon Radius, Muon Lifetime, Muon g-Factor, Muon Neutrino Mass, Electron Model, Mass Quantum

1. Introduction

The author has proposed a semi-classical model of the electron internal structure in publications [1]-[6]. The components of the structure model are:

- Outer mass shell comprised of a mass $\frac{3}{2\alpha}m_e$, where m_e is the mass of the electron and α is the fine structure constant. (Three positive mass quanta [3].) The outer radius of the shell is R_e and the inner radius is R_{ei}.
- Outer charge shell having a charge of $\frac{3}{2\alpha}e$, where e is the charge of the electron. The charge shell is embedded within the surface of mass shell, and has an outer radius of R_e and an inner radius of R_{eqi}.
- Central core comprised of negative mass $-\left(\frac{3}{2\alpha}-1\right)m_e$ and charge $-\left(\frac{3}{2\alpha}-1\right)e$. (Three negative mass quanta plus one electron mass.)

Granted, "negative mass" is a speculative concept, and is considered by many to be an "exotic material". As of yet, there is no experimental evidence of its existence. However, it is an essential component of the proposed electron model. Theoreticians such as Einstein have acknowledged the possibility of its existence.

The concept of a "mass quantum" was introduced in [3] and further discussed in [6]. It is defined as equal to $\frac{m_e}{2\alpha}$. It was recognized as a fundamental building block of the electron model. Experimental evidence of its existence beyond the electron is cited in [6]. It therefore seems reasonable to use the concept of such a mass quantum in this document when modeling the muon.

The muon is modeled by adding energy to the electron model. The mass of the muon will be seen to be not simply an integral multiple of the mass quanta [3], but rather a multiple plus the mass of the electron plus the mass of the muon and electron neutrinos. From the muon mass, its radius is calculated. The radius is close to the electron radius. Both radii are non-zero, in contrast to the assumption in the Standard Model that both radii are zero. The g-factor is calculated from the radius and magnetic moment. The material that embodies the muon and electron masses appears to be identical for both. From this observation, ranges of electron central core mass radius and density are calculated. The maximum radius of the central core positive charge is also estimated.

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	$7.2973525693\times10^{-3}$ [7]
Planck's constant	h	6.62607015×10^{-27} [8]
speed of light	c	2.99792458×10^{10} [9]
electron mass	m_e	$9.1093837139(28)\times10^{-28}$ [10]
electron charge	e	$-4.803204713\times10^{-10}$ [11]
electron radius	R_e	$2.8179403205\times10^{-13}$ [12]
electron magnetic moment	M_e	$-9.2847646917(29)\times10^{-21}$ [13]
electron antineutrino mass	$m_{\bar{\nu}_e}$	≤27 eV/c² [14]
muon mass	m_μ	$1.883531627\times10^{-25}$ [15]
muon magnetic moment	M_μ	$-4.49044830(10)\times10^{-23}$ [16]
muon g-factor	g_μ	2.00233184141 [17]
muon neutrino mass	m_{ν_μ}	≤0.150 MeV/c² [18]

2. Electron Creation

A model for the creation of an electron is described in Section 3 of [5]. A spherical shell of charge e is contracted from an infinite radius to a radius of R_e. Each increment of charge experiences a repulsive force due to the electric field generated by all of the other charge increments, which appear to be located at the center of the sphere. Contracting against the repulsive force increases potential energy of the charge shell. The electrical potential energy at R_e is m_ec^2. When the contracting force is removed, the potential energy is converted to mass m_e, the mass of the electron.

If the contracting force is removed at a radius greater than R_e, the electrical potential energy is less than the minimum required to create an electron. The charge shell expands due to the repulsive force of its own charge, releasing its potential energy. If the contracting force is removed at a radius less than R_e, the electron charge shell transitions to one of two possible states, depending on its potential energy. It transitions to the first state when the energy in excess of m_ec^2 is less than the equivalent mass of a viable particle, for example, an electron or neutrino. In this case, the charge shell expands to R_e. The potential energy is converted to an electron plus mass equivalent to the excess potential energy. The electron is in a metastable state due to the excess mass, which is finally converted to kinetic energy.

"Metastable state" is defined as an intermediate state during the transition between electrical potential energy and kinetic energy of the electron. It is simply a convenience within the framework of the model and may not actually exist. When the mass of the metastable state and all other attributes are consistent with that of an actual particle, then the lifetime of that state will be lifetime of the particle.

The charge shell transitions to the second state when the energy in excess of $m_e c^2$ is at least equal to that of a viable particle. The potential energy converts to an electron plus additional mass of the outer shell. The electron is now in a metastable state. The radius of the electron in this metastable state is less than R_e. If an additional contracting force is not applied to the charge shell within the lifetime of the metastable state, then the additional mass is restored to potential energy and the charge shell expands to R_e, converting all of the potential energy to kinetic energy. An example of the case where the force is applied within the lifetime is detailed below for the creation of a muon.

3. Muon Creation

The muon has a relatively short lifetime of 2.2 microseconds. It commonly decays into three particles: an electron, an electron antineutrino $\overline{\nu_e}$, and a muon neutrino ν_μ. The model for creating a muon described herein is a reversal of the muon decay. An electron is first created and then mass is added to it to create a muon.

The first step in creating a muon from an electron is the application of three sequential contracting forces to the electron's charge shell. Each force is removed when the electrical potential energy of the shell has increased to either the energy equivalence of an electron or one of the two neutrinos, each of which is a viable particle. The mass of each of these particles is created upon the removal of the corresponding force, and these three masses can be created in any order. After the three forces have been applied and removed, the electron is in a metastable state, with its outer shell having an additional mass equal to that of an electron plus the two neutrinos. The radius of the charge shell is defined to be R_μ. The second step in creating the muon is the application of another contracting force within the metastable state lifetime. The force is removed when the potential energy equals $\left(\frac{3}{2\alpha}-1\right)m_e c^2$. The mass equivalent to this energy is not equal to that of a viable particle. Therefore, when the force is removed, the charge shell expands under its own repulsive force to the original radius R_μ. All of the electrical potential energy is converted to additional mass $\left(\frac{3}{2\alpha}-1\right)m_e$ on the outer shell. The total mass of the electron in this metastable stable state is the original stable mass of an electron, $\left[\frac{3}{2\alpha}-\left(\frac{3}{2\alpha}-1\right)\right]m_e$, plus the additional mass of the electron m_e, plus the masses m_{ν_μ} and $m_{\overline{\nu_e}}$ of the two neutrinos plus the additional mass $\left(\frac{3}{2\alpha}-1\right)m_e$. The sum of these masses is

$$\left(\frac{3}{2\alpha}+1\right)m_e + m_{\nu_\mu} + m_{\overline{\nu_e}} \tag{1}$$

As calculated in the next two sections, this sum equals the mass of the muon.

Although the electron now has the mass of a muon, it is still in a metastable state, since its charge and angular momentum are not that of a muon. The electron can transition to a viable muon particle by partitioning its outer shell into two subshells. One has a negative charge of e and a positive mass of $\left(\frac{3}{2\alpha}+1\right)m_e + m_{\nu_\mu} + m_{\overline{\nu}_e}$, and the other has a negative charge of $\left(\frac{3}{2\alpha}-1\right)e$ and a positive mass of $\left(\frac{3}{2\alpha}-1\right)m_e$. The electric field inside the first subshell and due to that subshell is zero. The repulsive force on the second subshell due to its own negative charge is canceled out exactly by the attractive force due to the central core positive charge $-\left(\frac{3}{2\alpha}-1\right)e$. No energy is required or released to contract the second subshell inward to the central core and annihilate it. The second subshell negative charge and positive mass annihilate the central core positive charge $-\left(\frac{3}{2\alpha}-1\right)e$ and negative mass $-\left(\frac{3}{2\alpha}-1\right)m_e$. The remainder is the first outer subshell, which has the muon charge and mass. There is no central core. The transition from the electron metastable state to a muon is complete.

4. Muon Mass

The model proposed for the muon is the combination of the masses of an electron, three quantum masses, and two neutrinos. Not including the neutrinos, the model predicts a muon mass of

$$\left(\frac{3}{2\alpha}+1\right)m_e = 1.881579631\times10^{-25}. \quad (2)$$

The ratio of the actual muon mass m_μ to the mass predicted by this model is

$$\frac{m_\mu}{\left(\frac{3}{2\alpha}+1\right)m_e} = 1.001037424 \quad (3)$$

Therefore, the actual muon mass is 0.1% greater than the mass predicted by this model. The mass discrepancy is

$$\Delta m_\mu = m_\mu - \left(\frac{3}{2\alpha}+1\right)m_e = 1.95199600\times10^{-28} \quad (4)$$

It is proposed that this discrepancy equals the sum of the two neutrino masses. Therefore, these two masses are added to the model to yield a mass exactly equal to the actual muon mass m_μ.

5. Neutrino Masses

The neutrino mass upper limits have been determined, and are commonly expressed in the unit MeV/c^2. The sum of the neutrino masses $m_\mu + m_{\overline{\nu}_e}$ is predicted by the muon model to be $\Delta m_\mu = 0.109499$ MeV/c^2. (See [19] for unit conversion from CGS to MeV/c^2.) The upper limit to the mass sum has been determined to be 0.150 MeV [14] [18], so the sum of the neutrino masses predicted by the muon model is somewhat below this upper limit.

6. Muon Radius

The muon radius R_μ can be derived from its mass m_μ. The sequence of contracting the electron radius to create masses for the muon is described above. The repulsive force on the outer shell charge $\frac{3}{2\alpha}e$ is due to its own negative charge $\frac{3}{2\alpha}e$ and the positive central core charge $-\left(\frac{3}{2\alpha}-1\right)e$. The force required to contract the electron charge shell is

$$F=\frac{\left(\frac{3}{2\alpha}e\right)\left[\left(\frac{3}{2\alpha}\right)-\left(\frac{3}{2\alpha}-1\right)\right]e}{r^2}=\frac{3e^2}{2\alpha r^2} \tag{5}$$

where r is radius of the charge shell during the contraction. The electrical potential energy added to the charge shell when it is contracted to radius R_μ is

$$\int_{R_e}^{R_\mu}-F\mathrm{d}r=\frac{3e^2}{2\alpha}\left(\frac{1}{R_\mu}-\frac{1}{R_e}\right)=\left(m_e+m_{\nu_\mu}+m_{\overline{\nu_e}}\right)c^2 \tag{6}$$

From [4], the radius R_e of the electron is $R_e=\frac{e^2}{m_ec^2}$, and therefore $m_ec^2=\frac{e^2}{R_e}$. Solving Equation (6) for R_μ yields a muon radius predicted by the model of

$$R_\mu=\frac{R_e}{\frac{2\alpha}{3}\left(1+\frac{\Delta m_\mu}{m_e}\right)+1}=2.801391460\times10^{-13} \tag{7}$$

$$\frac{R_\mu}{R_e}=0.9941273203 \tag{8}$$

Therefore, the predicted muon radius is about 0.6% less than the electron radius.

7. Muon Magnetic Moment

The magnetic moment M of a spherical shell having a radius R, a charge q^-, and spinning at the speed of light c is [6]

$$M=\frac{g}{2}\frac{1}{3}q^-R \tag{9}$$

where g is the g-factor. The g-factor is exactly equal to 2 for a charge shell having zero thickness, and slightly greater for particles such as the electron and muon, where the charge shell thickness is non-zero. For the muon, $g=g_\mu$, $q^-=e$, and $R=R_\mu$. The muon g-factor g_μ is derived from Equation (9).

$$g_\mu=\frac{6M_\mu}{eR_\mu}=2.00233184 \tag{10}$$

where M_μ is the actual muon magnetic moment. Therefore, the model predicts the muon g-factor g_μ to be equal to the current measured value to within the precision of the magnetic moment.

8. Muon Angular Momentum

The muon mass is entirely in its outer shell with an outside radius of R_μ. The inner radius R_i of the outer shell must have a value such the spin angular moment of the outer shell is correct. The following is the $\frac{R_i}{R}$ derivation from [3] and is modified as described in Section 5 of [5].

The thickness of the outer shell is calculated from the spin angular momentum. To calculate the angular momentum as a function of the outer shell's outer and inner radii, a solid sphere is sliced into many nested cylinders, coaxial with the spin axis. The radius of each cylinder is r, its height is $2\sqrt{R^2-r^2}$, its thickness is dr, and its mass is dm. The period of rotation of each cylinder is T. The rotation speed v of a cylinder is $v=\frac{2\pi r}{T}$. The outermost cylinder has zero mass and a rotation speed of $c=\frac{2\pi R}{T}$. Therefore, the relative rotation speed of the cylinders is $\frac{v}{c}=\frac{r}{R}$. The momentum is calculated for the solid sphere and also for the mass at the center to be removed to create the hollow outer shell. The momentum of the outer shell is the difference between the momentum of these two masses. σ is the mass density of the outer shell if its spin were to be zero.

Let $x=\frac{r}{R}$. Then $r=Rx$, $\mathrm{d}r=R\mathrm{d}x$, and $\frac{v}{c}=x$. The mass m_o of a solid sphere with no hollow center is

$$\mathrm{d}m_o=\frac{\left(2\sqrt{R^2-r^2}\right)\sigma(2\pi r)}{\sqrt{1-\left(\frac{v}{c}\right)^2}}\mathrm{d}r=4\pi\sigma Rr\mathrm{d}r=4\pi\sigma R^3x\mathrm{d}x \tag{11}$$

$$m_o=4\pi\sigma R\int_0^R r\mathrm{d}r=2\pi\sigma R^3 \tag{12}$$

The spin angular momentum S_o of a solid sphere with no hollow center is

$$\mathrm{d}S_o=\mathrm{d}m_o vr=4\pi\sigma cR^4x^3\mathrm{d}x \tag{13}$$

$$S_o=4\pi\sigma cR^4\int_0^1 x^3\mathrm{d}x=\pi\sigma cR^4 \tag{14}$$

Let $x=\frac{r}{R_i}$. Then $r=R_ix$, $\mathrm{d}r=R_i\mathrm{d}x$, and $\frac{v}{c}=\frac{r}{R}=\frac{R_i}{R}x$. The mass m_i to be removed from the center to create the hollow is

$$\mathrm{d}m_i=\frac{\left(2\sqrt{R_i^2-r^2}\right)\sigma(2\pi r)}{\sqrt{1-\left(\frac{v}{c}\right)^2}}\mathrm{d}r=4\pi\sigma R_i^3\sqrt{\frac{1-x^2}{1-\left(\frac{R_i}{R}\right)^2x^2}}x\mathrm{d}x \tag{15}$$

$$m_i = 4\pi\sigma R_i^3 \int_0^1 \sqrt{\frac{1-x^2}{1-\left(\frac{R_i}{R}\right)^2 x^2}}\, x\mathrm{d}x \tag{16}$$

The spin angular momentum S_i corresponding to the mass removed to create the central hollow core is

$$\mathrm{d}S_i = \mathrm{d}m_i vr = 4\pi\sigma c R^4 \left(\frac{R_i}{R}\right)^5 \sqrt{\frac{1-x^2}{1-\left(\frac{R_i}{R}\right)^2 x^2}}\, x^3\mathrm{d}x \tag{17}$$

$$S_i = 4\pi\sigma c R^4 \left(\frac{R_i}{R}\right)^5 \int_0^1 \sqrt{\frac{1-x^2}{1-\left(\frac{R_i}{R}\right)^2 x^2}}\, x^3\mathrm{d}x \tag{18}$$

Leptons such as the muon and electron have a spin s of $\frac{1}{2}$. The spin angular momentum S is

$$S = \sqrt{s(s+1)}\frac{h}{2\pi} \tag{19}$$

The mass of the outer shell is $m^+ = m_o - m_i$. The mass volume density σ of outer shell for zero-spin is therefore

$$\sigma = \frac{m^+}{2\pi R^3\left(1-2\left(\frac{R_i}{R}\right)^3 \int_0^1 \sqrt{\frac{1-x^2}{1-\left(\frac{R_i}{R}\right)^2 x^2}}\, x\mathrm{d}x\right)} \tag{20}$$

The net spin angular momentum for the hollow outer mass shell is

$$S = S_o - S_i = \frac{cm^+R}{2}\left[\frac{1-4\left(\frac{R_i}{R}\right)^5 \int_0^1 \sqrt{\frac{1-x^2}{1-\left(\frac{R_i}{R}\right)^2 x^2}}\, x^3\mathrm{d}x}{1-2\left(\frac{R_i}{R}\right)^3 \int_0^1 \sqrt{\frac{1-x^2}{1-\left(\frac{R_i}{R}\right)^2 x^2}}\, x\mathrm{d}x}\right] \tag{21}$$

For the muon, $m^+ = m_\mu$ and $R = R_\mu$. Using the online integrator https://www.integral-calculator.com/, the solution to Equation (21) is

$$\frac{R_{\mu i}}{R_\mu} = 0.637167 \tag{22}$$

Therefore, the thickness of the muon mass shell is 0.36 times its radius and about 26% of the muon volume is hollow.

9. Mass Volume Densities

The zero-spin mass volume densities for the muon and electron outer shells can be calculated from Equation (20). For the muon, $m^+ = m_\mu$, $R = R_\mu$, and $\frac{R_i}{R} = \frac{R_{\mu i}}{R_\mu}$. For the electron, $m^+ = \frac{3}{2\alpha} m_e$, $R = R_e$, and $\frac{R_i}{R} = \frac{R_{ei}}{R_e}$. The muon and electron mass densities are

$$\sigma_\mu = 1.68264873 \times 10^{12} \quad \text{and} \quad \sigma_e = 1.64346892 \times 10^{12} \tag{23}$$

The ratio of the muon zero-spin mass volume density to that of the electron outer shell is

$$\frac{\sigma_\mu}{\sigma_e} = 1.02384 \tag{24}$$

Therefore, the muon mass volume density is slightly more than 2% higher than the electron outer shell density. Although the muon mass is more than 200 times that of the electron mass, the densities of their materials are remarkably close to each other. Conceivably in reality, the two densities are identical. If this were to be true, then the inner radius of the electron's outer shell would have to be slightly greater than previously reported [5]. Consequently, its angular momentum would be too great. However, this increase in angular momentum could be offset by increasing the angular momentum of the center core, since its mass is negative. A possible radius for the central core is calculated in the following section.

10. Electron Central Core Radius

In all previous models of the electron having a negative mass central core, it has been assumed that the radius of the central core is so small that its contribution to the total electron spin angular momentum is negligible. The radius could have been increased with a resulting increase in $\frac{R_{ei}}{R_e}$, but such an increase would have complicated calculations and served no purpose. However, given the apparent difference between the muon and electron mass densities, an increase in $\frac{R_{ei}}{R_e}$ would be useful in matching the two densities. As $\frac{R_{ei}}{R_e}$ increases, the spin angular momentum of the electron outer shell increases. Since the mass of the central core is negative, its spin angular moment is negative. Increasing the central core radius could therefore offset the increase in angular momentum of the outer shell.

Equation (20) equals the electron outer shell mass density σ_e for the parameters $m^+ = \frac{3}{2\alpha} m_e$ and $R = R_e$. The relative electron outer shell inside radius $\frac{R_{ei}}{R_e}$ is derived from Equation (20) when σ is set to σ_μ, the muon zero-spin outer shell mass density.

$$\frac{R_{ei}}{R_e} = 0.6561235 \tag{25}$$

The electron outer shell angular momentum increases to S_{os} when the outer shell radius is increased to this value. S_{os} is calculated from Equation (21) for the following parameter values: $m^+ = \frac{3}{2\alpha} m_e$, $R = R_e$, and $\frac{R_i}{R} = \frac{R_{ei}}{R_e}$.

$$S_{os} = 9.24158497 \times 10^{-28} \tag{26}$$

The radius of the central core R_{cc} must be increased to create an angular momentum that cancels the increase ΔS_{os} in the outer shell angular momentum.

$$\Delta S_{os} = S_{os} - S = 0.10872513 \times 10^{-28} \tag{27}$$

Assuming that the central core is solid and using the angular momentum equation in [20], the required radius R_{cc} of the central core can be calculated from

$$\Delta S_{os} = \frac{2}{5} \omega \left(\frac{3}{2\alpha} - 1 \right) m_e R_{cc}^2 \tag{28}$$

If the central core were to rotate at the same angular rate as the outer shell, that is $\omega = \frac{c}{R_e} = 1.06387 \times 10^{23}$, then

$$\frac{R_{cc}}{R_e} = \sqrt{\frac{5 \Delta S_{os}}{2c \left(\frac{3}{2\alpha} - 1 \right) m_e R_e}} = 0.1314 \tag{29}$$

(The central core rotation speed relative to the speed of light would be $\frac{v}{c} = \frac{R_{cc}}{R_e}$, so the non-relativistic Equation (28) is valid for calculating R_{cc}.)

Since the central core is assumed to be detached from the outer shell, because of the opposite polarity of their masses, it conceivably could rotate at a different speed, such as the speed of light. In this case, the radius R_{cc} would be very much smaller and the density of the core material would be very much greater. Setting $\frac{R_i}{R} = 0$, $S = \Delta S_{os}$, $m^+ = \left(\frac{3}{2\alpha} - 1 \right) m_e$, and $R = R_{cc}$ in Equation (21), then

$$\frac{R_{cc}}{R_e} = \frac{2S}{cm^+ R_e} = \frac{2 \Delta S_{os}}{c \left(\frac{3}{2\alpha} - 1 \right) m_e R_e} = 0.0138 \tag{30}$$

In this case, the mass volume density of the central core relative to the outer shell mass density would be

$$\frac{\sigma_{cc}}{\sigma_e} = \frac{m^+}{2\pi R^3 \sigma_e} = \frac{\left(\frac{3}{2\alpha} - 1 \right) m_e}{2\pi R_{cc}^3 \sigma_e} = 3 \times 10^5 \tag{31}$$

The maximum radius of the central core is limited by the inside radius of the outer shell, R_{ei}. In this case, the mass volume density of the central core relative to the outer shell mass density would be about

$$\frac{\sigma_{cc}}{\sigma_e} = 4 \tag{32}$$

Therefore, depending on the rotation speed of the central core, its radius relative to the electron radius can range from 0.66 to 0.0138, and its mass density relative to the outer shell mass density can correspondingly range from 4 to 3 × 10^5.

11. Central Core Charge Radius Upper Limit

The uncertainty in the value of the electron magnetic moment ΔM_e is approximately $\Delta M_e = \pm 1.4 \times 10^{-30}$ (Table 1). For the magnetic moment of the central core charge q_{cc} to have a negligible contribution to the total electron magnetic moment, the radius R_{ccq} of q_{cc} has to be less than the solution to Equation (33). The charge q_{cc} is assumed to be uniformly distributed within the charge sphere. The charge sphere is embedded in the central core at its center. Using the equation for magnetic moment in [21], the upper limit for the central core magnetic moment when the central core is spinning at the speed of light is

$$\Delta M_e = \frac{1}{5} q_{cc} \omega R_{ccq}^2 = \frac{1}{5}\left(\frac{3}{2\alpha} - 1\right) e \frac{c}{R_{cc}} R_{cc}^2 \left(\frac{R_{ccq}}{R_{cc}}\right)^2 \tag{33}$$

where $\omega = \frac{c}{R_{cc}}$ is the angular speed of rotation of the central core.

The upper limit for the central core charge sphere radius R_{ccq} relative to the central core radius R_{cc} is

$$\frac{R_{ccq}}{R_{cc}} = \sqrt{\frac{5\Delta M_e}{\left(\frac{3}{2\alpha} - 1\right) e c R_{cc}}} = 7.8 \times 10^{-10} \tag{34}$$

Equation (34) is the relative central core charge radius for the minimum central core radius and maximum rotation speed. The minimum rotation speed occurs for the maximum core radius $\frac{R_{cc}}{R_e} = \frac{R_{ei}}{R_e} = 0.6561235$. The angular rotation speed ω can be calculated from Equation (28).

$$\omega = \frac{\Delta S_{os}}{\frac{2}{5}\left(\frac{3}{2\alpha} - 1\right) m_e R_{cc}^2} = 4.3319 \times 10^{21} \tag{35}$$

(The central core rotation speed relative to the speed of light would be $\frac{v}{c} = \frac{\omega R_{cc}}{c} = 0.0265$, so the non-relativistic Equation (28) is valid for calculating ω.) By combining Equation (33) and Equation (35), the upper limit for the central core charge sphere radius R_{ccq} relative to the central core radius R_{cc} is

$$\frac{R_{ccq}}{R_{cc}} = \sqrt{\frac{2\Delta M_e m_e}{e \Delta S_{os}}} = 4.9 \times 10^{-10} \tag{36}$$

Therefore, independent of the central core rotation speed and radius, the electron central core charge must effectively be a point charge at the center of the core.

12. Elasticity

The modulus of elasticity of a material is commonly expressed as $k = -\frac{\mathrm{d}V}{V}\frac{1}{\mathrm{d}P}$, where V is the volume of the material and dV is the change in volume when the pressure P on the material is changed by dP. For the muon and electron, one of the pressures on the outer shell is the electrical pressure $P = \frac{q^- e}{4\pi R^4}$. The change in this pressure with a change in radius of the outer shell is $\frac{\mathrm{d}P}{\mathrm{d}R} = -\frac{q^- e}{\pi R^5}$. The elasticity modulus k is thus a function of the outer shell electrical charge q^-, and has a dimension of the inverse of pressure. Since q^- is very different for the muon and electron, the elasticity modulus will be very different. It is desirable to calculate the elasticity of the outer shell material independent of the charge embedded in its outer surface. A dimensionless modulus is preferred, such as

$$k = -\frac{\mathrm{d}V}{V}\frac{P}{\mathrm{d}P} \tag{37}$$

This modulus seems more reasonable for comparing the elasticities of the muon and electron, since it is not a function of their embedded charges.

The volume V of the outer shell is

$$V = \frac{4}{3}\pi R^3\left[1-\left(\frac{R_i}{R}\right)^3\right] \tag{38}$$

The relative change in volume is

$$\frac{\mathrm{d}V}{V} = 3\left[1-\left(\frac{R_i}{R}\right)^2\left[1-\left(\frac{R_i}{R}\right)^3\right]^{-1} R\frac{\mathrm{d}}{\mathrm{d}R}\left(\frac{R_i}{R}\right)\right]\frac{\mathrm{d}R}{R} \tag{39}$$

$\frac{\mathrm{d}}{\mathrm{d}R}\left(\frac{R_i}{R}\right)$ has been calculated numerically using Equation (21).

For the muon, $S = \sqrt{s(s+1)}\frac{h}{2\pi}$, $m^+ = m_\mu$, and $R = R_\mu$. Therefore, $\frac{\mathrm{d}}{\mathrm{d}R}\left(\frac{R_i}{R}\right) = -1.642\frac{1}{R}$ and $\frac{\mathrm{d}V}{V} = 5.69770\frac{\mathrm{d}R}{R}$. The dimensionless modulus of elasticity k for the muon is

$$k_\mu = -\frac{\mathrm{d}V}{V}\frac{P}{\mathrm{d}P} = -\left(5.69770\frac{\mathrm{d}R}{R}\right)\left(-\frac{R}{4\mathrm{d}R}\right) = 1.424425 \tag{40}$$

For the electron, $S = S_{os} = 9.24158497\times10^{-28}$, $m^+ = \frac{3}{2\alpha}m_e$, and $R = R_e$. Therefore, $\frac{\mathrm{d}}{\mathrm{d}R}\left(\frac{R_i}{R}\right) = -1.567\frac{1}{R}$ and $\frac{\mathrm{d}V}{V} = 5.82043\frac{\mathrm{d}R}{R}$. The dimensionless modulus of elasticity k for the electron is

$$k_e = -\frac{\mathrm{d}V}{V}\frac{P}{\mathrm{d}P} = -\left(5.82043\frac{\mathrm{d}R}{R}\right)\left(-\frac{R}{4\mathrm{d}R}\right) = 1.45511 \tag{41}$$

The difference between the muon and electron elasticities is about 2%. Conceivably, the two elasticities are identical with the difference in their values being the result of deficiencies in the model.

13. Lifetimes

The lifetime of the electron is on the order of eternity, whereas the lifetime of the muon is only two microseconds. A contributing factor to this difference could be their relative electromagnetic pressures. The electrical pressure on the outer shell is repulsive, whereas the magnetic pressure due to the spinning charge is inward. Equation (40) is derived from Equation (39) of [3] and expresses the relationship between the two pressures.

$$\frac{\text{electrical pressure } P_E}{\text{magnetic pressure}} = \frac{\dfrac{eq^-}{4\pi R^4}}{\dfrac{\left(q^-\right)^2}{12\pi^2 R^4}} = 3\pi \frac{e}{q^-} \tag{42}$$

where q^- is the outer shell charge and R is its radius. For the electron, $q^- = \frac{3}{2\alpha}e$, and the ratio equals $2\pi\alpha = 0.046$. The inward magnetic pressure is 22 times stronger than the electrical outward pressure, helping to hold the electron together. For the muon however, $q^- = e$ and the ratio is 9.42. Therefore, for the muon, the outward electrical pressure is much greater than the inward magnetic pressure. The only thing holding the muon together is the tensile strength of the outer shell material.

14. Summary

A semiclassical model has been proposed for the creation of a muon from an electron. The muon creation is modeled by adding three mass quanta, each quantum having a mass of $\frac{1}{2\alpha}$ times the electron mass, to the electron model. The electron model consists of an outer positive mass shell and a negative mass central core. The muon radius is calculated to be slightly less than the electron radius. The muon mass is modeled to be a hollow, spherical shell. Its inside radius has been calculated. The muon and electron outer shell zero-spin mass densities and elasticities have been calculated, and are seen to be nearly identical, suggesting that the muon and electron positive mass shells are comprised of the same material. Assuming that the muon and electron outer shell mass densities are truly identical has enabled the calculation of a range of values for the electron's central core radius. Although the central core radius is now considered to be non-zero, the radius of the positive charge at the center of the core is still effectively zero. The model predicts the g-factor of the muon to be exactly equal to the actual value. Comparing the electromagnetic forces within the muon to those within the electron provides insight into why the lifetime of the muon is so much less than the electron lifetime. The mass of the muon neutrino has been calculated.

Conflicts of Interest

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

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