The QED Coupling Constant for an Electron to Emit or Absorb a Photon is Shown to be the Square Root of the Fine Structure Constant α

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Abstract

The QED probability amplitude (coupling constant) for an electron to interact with its own field or to emit or absorb a photon has been **experimentally** determined to be -0.08542455. This result is very close to the square root of the Fine Structure Constant α. By showing theoretically that the coupling constant is indeed the square root of α we resolve what is, according to Feynman, ***one of the greatest damn mysteries of physics***.

Keywords: Feynman Diagram; Coupling Constant; Fine Structure Constant; QED; GeometroDynamic Model-GDM; Electron

1 The Riddle

1.1 Feynman on the QED Coupling Constant and the Fine Structure Constant Riddle [1]:

There is a most profound and beautiful question associated with the observed coupling constant, e, the amplitude for a real electron to emit or absorb a real photon. It is a simple number that has been ***experimentally determined*** *to be close to -0.08542455. (My physicist friends won't recognize this number, because they like to remember it as the inverse of its square: about 137.03597 with about an uncertainty of about 2 in the last decimal place. It has been a mystery ever since it was discovered more than fifty years ago, and all good theoretical physicists put this number up on their wall and worry about it.) Immediately you would like to know where this number for a coupling comes from: is it related to p or perhaps to the base of natural logarithms? Nobody knows.* ***It's one of the greatest damn mysteries of physics****: a magic number that comes to us with no understanding by man. You might say the "hand of God" wrote that number, and "we don't know how He pushed his pencil." We know what kind of a dance to do experimentally to measure this number very accurately, but we don't know what kind of dance to do on the computer to make this number come out, without putting it in secretly!*

1.2 The Known Feynman Diagram of the Electron Interacting with its Own Field

Fig. (1) represents this interaction. The field is considered, in QED, a "sea" of photons - excitations of the electromagnetic field - and hence the moving electron interacts with its "own field" by absorbing and emitting photons.

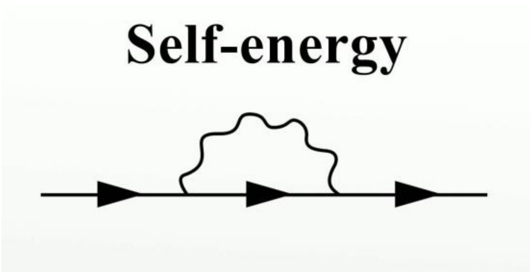

Fig. (1) Feynman Diagram

This understanding yielded the known results of QED, but left open long-standing issues, as Feynman himself expressed. To cope with these open issues, we have to take a new look at Feynman diagrams. This is expressed, as explained, by Fig. (2).

Note that Fig. (1) tells us **nothing** about the mechanism of interaction between the electron and the photon. Considering both the electron and the photon as point-like and structureless, as they are considered in the current paradigm, leaves us helpless.

2 The Paradigm Shift Required to Resolve the Riddle

2.1 Our Paradigm Shift

Our alternative to the paradigm is the GeometroDynamic Model (GDM) of the Physical Reality (see Section 7). In the GDM Elementary Particles (with rest mass) at “rest” are circularly rotating longitudinal wavepackets. Only their virtual geometric centers, relative to space, are at rest. When their geometric centers move in a straight line, relative to space, the wavepackets describe spirals. Note that space is considered a special frame and velocity, relative to it, is determined by the CMB Doppler shift. Note also that there is no rest - only motion, of waves and wave packets, at the transverse and longitudinal waves’ velocities c and c_L respectively. Elementary Particles (without rest mass) are transverse wavepackets that move at the velocity c - the photon and the graviton are examples.

The electron at “rest” in our model [2], is the negative elementary charge of radius r_e, circulating with a radius R_e, at the tangential velocity c_L. In this paper we define these radii, and the term “elementary charge” and also calculate them.

2.2 Our Idea How the Electron Interacts with its Own Field and the Prof Required to Resolve the Riddle

In Fig. (2) the electron at “Rest” circulates, with a radius R_e. At A the electron emits a photon that moves at the velocity c towards B. As we show here and in [2] $c_L > c$, where:

$$c_L = \pi/2\cdot(1+\pi\alpha)\cdot c \sim \pi/2\ c \qquad \text{and hence } c_L = 1.6068\cdot c \tag{1}$$

At B the photon is absorbed and reemitted by the electron towards the point C. This process is probabilistic, it goes on and on continuedly and from each and every point on the circular track. The probability, p, for this process to take place is the time that the photon passes by the elementary charge (and hence is able to interact with it) divided by the time for the electron to move from A to B. This time's ratio is the ratio of the diameter $2r_e$, of the elementary charge of the electron, to the diameter $2R_e$ of the circle, namely:

$$p = r_e/R_e \qquad (2)$$

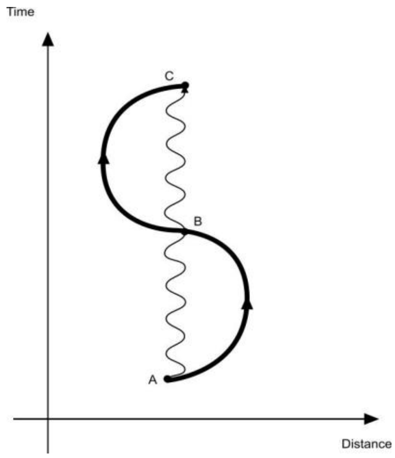

Fig. (2) Our Electron's Feynman Diagram

Our goal, therefore, is to prove (Section 7) that:

$$r_e/R_e = \alpha \qquad (3)$$

where α is the Fine Structure Constant. Note that

$$\alpha = Q^2/c\hbar = 1/137.03597 \text{ (Q is the elementary charge)} \qquad (4)$$

And indeed, if we prove equation (3) then the square root of (4) should be equal to the square root of p, which in QED [1] is:

$$\text{Coupling Constant} = -\ 0.08542455 \qquad (5)$$

2.3 Our Idea How the Electron Interacts with its Own Field – the Classical Way

Based on our Model of the electron we use Fig. (2), our modified Feynman diagram, instead of Fig. (1). Fig. (2) represents a classical approach to the interaction of an electron with its own field.

The buildup of a field around a suddenly created charge propagates, from the charge onwards, at velocity c. The sudden destruction of the charge causes the field around it to vanish at the same speed.

Imagine, see Fig. (2), a circulating charge (longitudinal wavepacket) that moves with velocity c_L, where $c_L > c$.

In this case, if to move along half a circle takes less time than for the field to vanish along the diameter, **the charge will be affected by its own field** created when it passed the opposite point on the diameter, **as if** the charge, still exists on the other side of the diameter. We refer to this virtual charge as the **image** of the charge. **Self-interaction** is thus the interaction of a charge with its **image**, as we phrase it. Imagine the electron charge circulating with velocity c_L around a point. Self-interaction occurs if the time to circulate a half circle, $\pi r / c_L$, is shorter than, or equal to, the time for its propagating or retreating field to cross the diameter $2r/c$. Thus, self-interaction takes place if at least:

$\pi r_e / c_L = 2 r_e / c$. The requirement for self-interaction is thus:

$$c_L / c \geq \pi/2 \tag{6}$$

The minimal value of this ratio is:

$$c_L / c = \pi/2 \tag{7}$$

By constructing a more accurate model of the electron (Section 7.2 in [2]), we arrive at (1), which is more accurate than the ratio (7).

Note that the edge of the electric field moves at the velocity c, whereas the charge moves at c_L.

Note, also, that our approach leads to the derivation and calculation of the elementary particles' masses. The electron mass equation and calculation, for example, appear in Appendix A.

3 On the Elementary Charge Radius r_e

We consider **Electric Charge** as merely a space deformation, which is a longitudinal wavepacket [3], [2], [4], [5], [6]. **Positive charge** is a contracted zone of space and **negative charge** - a dilated zone. **The field** of the electric charge is a smooth continuation from this zone to infinity, of a diminishing contraction or dilation of space. There is no separation between the charge and its field; they are a continuous deformation of space – Einstein's vision. The calculated electrostatic energy of the elementary charge, and that of its field are the same, but both express actually the **total** energy of the charge and its field. Thus, r can only be considered as an artificial "border" between the "charge" and the "field". We **define** - freely invent (Einstein's expression) - this r_e to be a virtual border for which on both of its sides resides the same **half** of the above total energy, Section 4. Based on this understanding and using General Relativity we arrive, Section 5, at the elementary charge radius r_e.

4 The Electrostatic Energy of an Electric Charge and the Issue of Whether it is in the Charge or in the Field

This long-standing open issue, addressed by Feynman [7] and others, is: The energy needed to create a charge Q of radius r, by bringing in from infinity infinitesimal amounts of charge, despite repulsion, is:

$U = Q^2/2r$

The energy density of the electrostatic field $E = Q/r^2$ is:

$\epsilon = 1/4\pi\ E^2$

and the entire energy in the field is also: $U = \int_r^\infty \epsilon d\tau = Q^2/2r$

Thus, we ask where is the energy, in the field or in the charge?

Our model of the elementary electric charge solves this issue.

In our model there is no separation between the charge and its field; they are a continuous deformation of space – Einstein's vision. The above calculated energy, in both cases, is the same **total energy** of the charge and its field.

Thus, r can only be considered as an artificial "border" between the two. We **define** - freely invent (Einstein's expression) - this r to be a virtual border for which on both of its sides resides the same half of the above U.

Hence, for r calculation **alone** we take:

$r = Q^2/4U$

Note that U is the space energy of strain, be it contraction or dilation.

5 A Derivation and Calculation of the Elementary Charge Radius r_e

5.1 The Result Obtained in 5.2

$r_e = \sqrt{2}/(2s^2) \cdot \sqrt{G\alpha\hbar c}$ where $s = 1$, $[s] = LT^{-1}$ (8)

r_e (calculated) $= 0.8774 \cdot 10^{-13}$cm (9)

We show that this radius is well within the experimental error range, [8], of the Proton /Anti-Proton **charge radius**, which was **measured** to be:

r_p (measured) = $0.8768(69) \cdot 10^{-13}$cm (10)

and **indeed**:

r_e (calculated) / r_p (measured) = $0.8774 \cdot 10^{-13} / 0.8768 \cdot 10^{-13} \sim 1.0007$

5.2 The Derivation of Equation (8) Here and in the Next Sub Sections

The Schwarzschild metric is the solution to the Einstein field equations of General Relativity (GR) outside a spherical mass. In spherical coordinates (t, r, θ, φ), the line element for the Schwarzschild metric, [9], is:

$$ds^2 = \left(1-\frac{r_s}{r}\right) c^2dt^2 - \left(1-\frac{r_s}{r}\right)^{-1}dr^2 - r^2\, d\Omega^2 \quad (11)$$

where c is the speed of light, t is the time coordinate (measured by a stationary clock at infinity), r is the radial coordinate and $d\Omega^2$ is a 2-sphere defined by: $d\Omega^2 = d\theta^2 + \sin^2\theta\, d\theta^2$.

The Schwarzschild, gravitational **black hole** radius, r_s , see the metric (11), in cgs units, is:

$$r_s = \frac{2GM}{c^2} \quad (12)$$

or since $M = U/c^2$:

$$r_s = \frac{2GU}{c^4} \quad (13)$$

Note that equation (2) is also the result of equating the potential energy GMM'/r_s of a test mass M' , in the field of M, to its ultimate kinetic energy of escape from the black hole $1/2\, M'c^2$.

We now show that (11) and (12) are also relevant to the bivalent elementary charges. The self-energy U of a charge Q, accumulated in a sphere with radius r is $U = Q^2/2r$. This U, Section 4, is the strain energy of a continuous space of both the charge and its field. We set a virtual border, of radius r, to **artificially** divide the energy **equally** between the space zone of the charge and that of its field. This is our **definition** of r. Hence:

$r = Q^2/4U$

However, for calculating the **total energy** U, of the charge and its field, and the mass M of the electron **we retain** the relations: $U = Q^2/2r$ and $M = U/c^2$.

Inserting the above expression $r = Q^2/4U$ in (3) and notating $r = r_S$ gives the r_S for a black hole:

$$r_S = \frac{GQ^2}{2r_S c^4} \tag{14}$$

To explain the quantization of charge it has been suggested that we conside Kallosh and Linde the elementary charge to be, not only a contraction or dilation of space, but a black or white (respectively) hole [10], [11]. Thus, the radius of the elementary charge is related to the Schwarzschild radius. This consideration, as we show, yields the results mentioned in the Introduction.

By definition, an elementary charge curves space since it is the dilation or contraction of space, [12]. This curving, as we show, is orders of magnitude larger than the gravitational curving by the energy/momentum of the particle, which is related to its spin, as we show elsewhere.

The **equality** of the absolute values of the bivalent charges is related to their creating photon in the pair production process, Section 5 in [2].

Since (4) becomes $r_S{}^2 = \frac{GQ^2}{2c^4}$, its square root gives:

$r_S = \pm\sqrt{\frac{GQ^2}{2c^4}} = \pm\frac{Q\sqrt{G}}{c^2\sqrt{2}}$ This r_s is obtained for the self-energy of the elementary charge Q.

We **re-notate** it as r_{SQ} and the above equation becomes:

$$r_{SQ} = \pm\sqrt{\frac{GQ^2}{2c^4}} = \pm\frac{Q\sqrt{G}}{c^2\sqrt{2}} \tag{15}$$

In (15) r_{SQ} is positive for a positive charge and negative for a negative charge. A negative r_{SQ} means a negative radius of curvature. In this case we have a "white hole" instead of a black hole or a "repulsion", as Kallosh and Linde [13] name it. Note that in [13] the authors use String Theory. This white hole reflects incoming particles like photons.

5.3 The Curving by the Elementary Charge and its Schwarzschild Radius

The "gravitational" curving K_M by **a mass** (energy), see [14] and [15], is given for $r \geq r_S$ by:

$$K_M = 1/R_c{}^2 = r_S/r^3 \tag{16}$$

R_c is the Gaussian radius of curvature.

Using (12), the force F_M that two equal masses M apply on each other is:

$$F_M = \frac{GM^2}{r^2} = \frac{c^4}{4G}\frac{r_S^2}{r^2} \tag{17}$$

Thus, according to (16) and (17), **force is related to space curvature**.

Hence, we substitute in (17) the r_{SQ} of (15), instead of r_s of (12). This step is legitimate since we relate only to the "gravitational" curving due to mass/energy of the particle not to its charge; thus, the expression for the curvature remains the same. This substitution gives:

$$F_M = \frac{GM^2}{r^2} = \frac{c^4}{4G}\frac{r_{SQ}^2}{r^2} \tag{18}$$

And (16) can be rewritten as:

$$K_{SQ}\,(\text{energy}) = 1/R_c^2 = r_{SQ}/r^3 \tag{19}$$

We now suggest expressing the **electrical charge** curving K_Q by the net elementary charge (**not** the curving by its self-energy) in the same way as K_M is expressed in (16). This is possible since charge is merely the curvature (deformation) [10] of space:

$$K_Q(\text{charge}) = 1/R_{cc}^2 = r_Q/r^3 \tag{20}$$

where r_Q the Schwarzschild radius of the **net elementary charge**, which **is not** the radius r_{SQ} due to its self-energy. And R_{cc} is the Gaussian radius of curvature of the net elementary charge. We **assume** that:

$$r_Q = k\, r_{SQ} \tag{21}$$

Thus the force F_Q that two equal charges Q apply on each other is, in similarity to (18):

$$F_Q = \frac{Q^2}{r^2} = k^2\,\frac{c^4}{G}\frac{r_{SQ}^2}{r^2} \tag{22}$$

The ratio of the forces F_Q and F_M becomes:

$$F_Q / F_M = \frac{Q^2}{GM^2} = 4\,k^2 \tag{23}$$

This ratio for the elementary charge Q_e and the electron mass M_e is:

$$F_Q / F_M = \frac{Qe^2}{GMe^2} = 4.162\ 10^{42} = \text{the numerical value of } 5.094\ c^4 \tag{24}$$

The **numerical value** of c^4 can be written as c^4/s^4, where s = 1 and [s] = LT^{-1}. Thus, according to (23) and (24):

$k^2 = 5.094/4\ c^4/s^4 = 1.273\ c^4/s^4 \sim c^4/s^4$ and

$k = 1.128\ c^2/s^2 \sim c^2/s^2$ (25)

This result means that r_Q (due to the intrinsic curvature of charge) is ~ c^2/s^2 larger than r_{SQ} (due to the electromagnetic self-energy of the charge).

Regarding these Schwarzschild radii, we raise a conjecture. It **leans** on our assumption, equation (21), which is $r_Q = k\ r_{SQ}$, and the experimental result (25) for the value of k.

CONJECTURE

r_Q (due to the **intrinsic curvature of charge) = r_{SQ} (**due to the **self-energy of charge) c^2/s^2** (26)

This conjecture for the relevant curvatures (19) and (20) is:

$K_Q = c^2/s^2\, K_{SQ}$ (27)

By using (26); replacing c with s, s =1, [s] = LT^{-1}, in the denominator of (15) **our conjecture** gives: **The Elementary Charge's Radius r_e**

$$r_e = r_Q = \frac{\sqrt{2}Q\sqrt{G}}{2s^2} \qquad \text{our previous (8)} \tag{28}$$

This relation (28) enables us to derive and calculate radii and masses of the elementary particles.

The **proton charge radius** (29), as we relate in Sub Section 5.1 and Section 6, is that expressed by (28):

$$r_p = \frac{\sqrt{2}Q\sqrt{G}}{2s^2} \tag{29}$$

6 On the Proton's Charge Radius r_p and the Electron's r_e

6.1 The Essence of the Proton's Charge Radius

The radius of the proton's elementary charge was measured, but not that of the electron. We relate to the proton because it enables us to compare our theoretical result (18) to measured values.

In [2] we present a model of the quarks that construct the proton and derive and calculate their masses. We show that a quark is a "twisted" electron and the anti-quark - is a "twisted" positron. This is why we consider the Proton's Charge Radius to be that of the elementary charge.

6.2 The Calculated Versus the Experimental Results

By substituting the value for Q in (18), as it appears in $\alpha = Q^2/\hbar c$, we get for both the proton and the electron:

$$r_e = r_p = (\sqrt{2}/2s^2)\sqrt{G\alpha\hbar c} \quad (30)$$

Inserting the CODATA 2014 values $G = 6.67408(31) \cdot 10^{-8} cm^3 gr^{-1} sec^{-2}$ and

$Q = 4.80320425(10)\ 10^{-10}$ esu in (29) gives:

$$r_e = r_p \text{ (calculated)} = 0.8774\ 10^{-13} \text{ cm} \quad (31)$$

This is the radius of the elementary charge and also that of the proton and electron charges.

This result is well within the experimental error range, see [8]:

$$r_p \text{ (measured)} = 0.8768(69)\ 10^{-13} \text{cm} \quad (32)$$

This, and the results presented in the next sections, confirm our conjecture.

Our result (31) is somewhat larger than (32), the measured electronic hydrogen proton charge radius. And (32) is larger than that for the muonic hydrogen $0.84087(39) \cdot 10^{-13}$cm [16].

This discrepancy, between the measured results, is termed the **"Proton radius puzzle"** [16].

Note the possibility that it is the QED vacuum polarization that affects the measurements. Our result is for the bare proton whereas vacuum polarization in electronic hydrogen and muonic hydrogen affects the measurements to give smaller results. Note that the muon vacuum polarization is larger since the muon is about 200 times closer to the proton than the electron

7 A Simplified Derivation of the Electron's Circulation Radius Re and the REQUIRED PROF $r_e/R_e = \alpha$

To retain exactly the $1/2\,\hbar$ angular spin momentum, contributed by the photon in the pair production process, the elementary charge at "rest" has to participate in a circulation (this circulation is a compound circulation detailed in [2], with somewhat different notations!). The end result is a circulation with a tangential resultant velocity c and radius R_e. Hence:

$1/2\, \hbar = U/c\, R_e$ or $R_e = 1/2\, c\hbar / U$ but $U = Q^2/2r_e = 1/2\, Q^2/r_e$.

(Note that in [2] we prove that the energy of the electron and other particles is purely electromagnetic. Appendix A gives our result for the electron/positron mass. The match to the experimental result proves our case). Therefore:

$R_e = 1/2\, c\hbar / U = 1/2\, c\hbar/(1/2\, Q^2/r_e) = r_e\, c\hbar/Q^2$ or

$r_e/R_e = Q^2/c\hbar$ but $\alpha = Q^2/c\hbar$ Hence:

$$r_e/R_e = \alpha \tag{5}$$

Q.E.D.

8 The Stability of the Self-Circulation and the Anomalous Gyroscopic Moment as a Classical Attribute

The self-circulation is kept stable by the **attractive** Lorentz force $\mathbf{F} = Q/c\, \mathbf{v}\times\mathbf{B}$, towards the center of the circulation. The magnetic field **B**, which the charge senses, is created by **the circulation of its image**. This force balances the **repulsive** force $F = Q\cdot Q/(2R_e)^2$ between the charge and its image. The magnetic field created by the circulating charge is $\mathbf{B} = 1/c\, \mathbf{v}\times\mathbf{E}$. Hence: $\mathbf{F} = (Q/c)\mathbf{v}\times\mathbf{B} = (Q/c)\mathbf{v}\times(1/c)\mathbf{v}\times\mathbf{E}$ but v = c and this equation becomes $\mathbf{F} = Q\mathbf{E}$ or $F = Q\cdot Q/(2R_e)^2$ This centripetal force balances the repulsive force above.

The **anomalous gyroscopic moment** is considered a quantum mechanical phenomenon that **cannot** be explained by classical physics.

However, the circulation of the self-interacting charge with its own “image” is a current of **“two”** charges that double the electron’s own field **E**, locally, and hence double $\mathbf{B} = 1/c\, \mathbf{v}\times\mathbf{E}$.

These circulating “two” charges contribute the factor 2 in the anomalous gyroscopic moment, as Dirac showed. The additional Schwinger [17] correction factor $\alpha/2\pi$ is discussed in [2].

9 Some Remarks on Our–SpaceTime GeometroDynamic Model (GDM) of the Physical Reality [4,5,6] - Our Paradigm Shift

9.1 The GDM Sole Postulate Is:

The three-dimensional elastic space is all there is.

Necessarily: The deformation of space is described by a metric.

Space vibrates longitudinally (recently **revealed**) and transversally with only two corresponding velocities.

There is no rest - only motion at the waves' velocities. Elementary particles at "rest" are circularly rotating wavepackets. Their virtual geometric centers are at rest. When they move the wavepackets describe spirals. The only one vector field in the GDM is the gradient in space density, whereas the density itself is a scalar field.

9.2 In Contrast to the Conventional Scientific Inductive Method the GDM is a Freely Invented (Einstein's Expression) Idea.

With this idea alone, we can infer logically the laws of physics and construct a tentative physical theory isomorphic to the entire physical reality. The GDM is thus a non-phenomenological theory. The GDM specificity is also expressed by new suggested experiments and observations, which enable its "validation" or falsification.

9.3 In the Past, Space Was Considered a Reference Frame

This frame is meaningless without the presence of material bodies. Today, space is considered a kind of elastic foam or fluid elastic foam with nonlinear properties.

9.4 In the GDM Nothing is Alien to Space

Space, not yet clearly modeled, is the **one and only one** basic physical entity that is needed to construct known physics and beyond. And space density is the **sole** parameter in the laws of physics.

9.5 Charge

Charge is not alien to space; it is a drastically curved zone of space. Contracted space is positive charge whereas dilated space is negative charge, [3]. Current theories are unable to derive the attributes of electric charge, which are: bivalency, stability, quantization, equality of the absolute values of the bivalent charges, the electric field it creates and the radii of the bivalent charges. The GDM derives it all.

9.6 Electric Charge Density q

q is defined by equation (1) in [3], based on space density only. This definition alone, without any phenomenology, yields the theory of Electrostatics. Together with the Lorentz Transformation it yields, as an approximation, the entire Maxwell Electromagnetic theory. The **non**-approximated theory is **non**-linear, since the field is part of the charge that creates it - like in gravitation. This is the specificity of the theory that resembles QED results.

For more on the GDM see our eBook [5] and our website [6].

10 Summary

QED formalism yields very important results, but it is **not the whole story**, as Feynman himself admitted.

Acknowledgements

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Appendix A: Example of Our Derived and Calculated Electron (Positron) Purely Electromagnetic Mass

We have constructed models of the electron and the other elementary particles. We have derived and calculated the masses of those elementary particles with rest masses. Our results comply with the 2014 CODATA.

The mass of the Electron (Positron) is:

$$M_e = \frac{s^2\sqrt{2}}{\pi(1+\pi\,\alpha)} \cdot \sqrt{G^{-1}\alpha\hbar c^{-3}} \qquad s = 1,\ [s] = LT^{-1}$$

G - gravitational constant, α - fine structure constant, ħ - Planck constant, c - light velocity.

M_e (calculated) = 0.910,360 $\cdot 10^{-27}$gr

M_e (measured) = 0.910,938,356(11) $\cdot 10^{-27}$gr

M_e (measured) / M_e (calculated) = 0.910,938 $\cdot 10^{-27}$ / 0.910,360 $\cdot 10^{-27}$ ~ 1.0006

This result speaks for itself.

A dimensionality check: $[G^{-1}] = ML^{-3}T^2$, $[\alpha] = 1$, $[\hbar] = ML^2T^{-1}$, $[c^{-3}] = L^{-3}T^3$.

Thus:

$$M = \left[s^2\sqrt{G^{-1}\alpha\hbar c^{-3}}\right] = L^2T^{-2}(ML^{-3}T^2\cdot ML^2T^{-1}\cdot L^{-3}T^3)^{1/2} = L^2T^{-2}(M^2L^{-4}T^4)^{-1/2}$$

$$= L^2T^{-2}ML^{-2}T^2 = M$$