# The Physical Electron

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## Abstract

The electron is generally regarded as an elementary particle with no known components or substructure, due in part to the inability to measure its size. This measurement problem raises the possibility that this current characterization could be due to unusual operational and structural characteristics of the electron. This possibility provided the rationale for the current work which is the evaluation of a potential causative model of the electron based on the interactions of two postulated fundamental massless particles. It is shown that this model, when evaluated in the context of the fundamental constants, defines and evaluates properties of the massless particles and additional properties of the electron and proton. The equations and numerical values for the fundamental constants are presented in terms of the properties of the two massless particles and the new properties of the electron and proton. The fact that these equations accurately calculate the known values of the fundamental constants and satisfy the equations of the geometric model suggests that the electron could possess an unusual dynamic physical structure.

## Introduction

As one of the primary constituents of matter, the electron is a principal participant at the atomic level in every field of natural science. However, the characterization of the electron as a fundamental point particle having little or no size and no substructure[1] differs significantly from that of its structured companions, the proton and neutron. This dichotomy between function and composition is further indicated by additional functional characteristics of the electron such as its wave-like nature, the long range of its electrostatic force, its role in superconductivity, and its role as the bonding agent in condensed matter[2]. One possible explanation of this dichotomy is that the electron actually possesses an unusual dynamic structure formed from fundamental massless particles. The small size of the massless particles and the nature of the dynamic structure may have prevented the measurement of its size.

Based on this rationale, the strategy was to formulate a geometric model of the functional mechanisms for both the electron and proton that is sufficiently comprehensive to embrace the known roles of these particles. The functional mechanisms are assumed to result from the interactions of two fundamental massless particles. It is hypothesized that the known values of the fundamental constants including the masses of the electron and proton are functions of the properties of these massless particles. Accordingly, the properties of the massless particles may be implicit in the values of the fundamental constants. It was expected that these properties would emerge given the correct geometric model when evaluated in this framework.

The result has been the derivation of the values of the properties of the postulated massless particles and additional properties of the electron and proton. In addition, equations for the fundamental constants have been developed in terms of these new properties. The single claim in this paper is that these properties accurately calculate the known values of the fundamental constants and satisfy the equations of the geometric model. For this work, the fundamental constants are considered to be the universal gravitational constant, the Planck constant, the fine structure constant, the elementary charge, the Rydberg constant, and the electron and proton masses. The values calculated from the developed equations are comparable to the NIST 2010 CODATA values[3] and add three digits to the value of the universal gravitational constant and present an exact value for the ratio of the proton and electron masses.

## Development of the Postulated Physical Model

This work is based on the following three postulates:

1. All processes in the universe emerge from the interactions of two massless particles.
2. The concepts of mass, force, and all resultant static and dynamic properties of matter result from the action of the two massless particles in the formation and function of the two stable structured particles, the electron and proton.
3. All measured values of the traditional fundamental constants including the electron and proton properties are the result of actual physical mechanisms.

The basic premise for the physical model as seen in the postulates is that the entire universe of mass and energy is solely the result of collisions between the only existent foundational entities in the universe, herein designated as characteristic one (C1) and characteristic two (C2) particles. The properties of these characteristic massless particles are considered to be implicit in the values of, and relationships between, the fundamental constants. When analyzed in the context of the proposed physical model, these implicit properties are delineated. The description of this physical model presented in the following paragraphs is based on the calculations reported below.

### Interactions of C1 and C2 Particles

Both the C1 and C2 particles are regarded as smooth, rigid, massless spheres. Their collisions are accurately represented by a billiard ball model with purely kinematic responses due to the massless property. During each collision, the tangential component of velocity for each particle is maintained, and their normal components are instantaneously exchanged. The conservation principles for these kinematic collisions are (1) conservation of C1 and C2 numbers, (2) conservation of the squares of the particle speeds, and (3) conservation of the vector sum of the particle velocities. These principles are analogous to the conservation of mass, energy, and momentum, respectively, for dynamic collisions of rigid spheres.

The C1 particle is small with a large number density, and it is the activator for all forces (gravity, electromagnetic, strong and weak nuclear) and actions in the universe. The C2 particles are much larger and less numerous than the C1 particles. As a result, under equilibrium conditions, the net movement of any C2 particle is small compared to its diameter. This is due to the high collision rate with the C1 particles, which have an exceptionally large number density. The result is that the C2's form a flexible and responsive grid system which suggests the concept of space as the three-dimensional region between adjacent C2 particles in the grid. This flexible grid system is shaped by the contour of objects because of the attraction of the C2's to the objects. Therefore, as expected, space is curved, consistent with general relativity.

Direct C1-C1 collisions are exceptionally rare due to their large mean free path related to their small size. There is no apparent limit to finite smallness at the most fundamental level. The C2-C2 direct collisions also rarely occur due to intervening C1-C2 collisions. Therefore, almost all collisions are C1-C2 which act as an intermediary for both indirect C1-C1 and C2-C2 collisions. In addition, all collisions are two-particle collisions as absolute simultaneity does not exist because of the instantaneous response condition.

The massless C1 and C2 particles have the same equilibrium isotropic speed distribution and, therefore, the same average speed, $V_{C1avg} = V_{C2avg}$. Since the interaction of the C1 and C2 particles is the cause of all forces and actions, no object with mass can exceed this average speed, consistent with special relativity[4]. This result suggests an important extension to the theory of special relativity in that this average speed is the speed of light in a vacuum, c. That is, $V_{C1avg} = V_{C2avg} = c = 299{,}792{,}458$ m/s. In this context, the speed of light is regarded herein as a fundamental constant and a measured property of the massless particles.

This average speed is also the propagation speed of any disturbance to the C2 grid system, which includes all electromagnetic radiation. While the average speed of the fundamental particles is the speed of light in a vacuum, the speed distribution includes instantaneous speeds from zero to hyperluminal. The hyperluminal speeds play a vital role in the function of the electron and proton as described below.

**Physical Mechanisms of the Electron and Proton**

The physical model for the electron is a pulsating shell of C2 particles, one C2 particle thick. Specifically, a precise number of captive C2 particles maintain a dynamically stable, fully contracted rotating electron shell for an exact and brief period of time. The number of C2 particles in the electron shell is determined as one of the emergent properties from the model and fundamental constants. The rotation and resulting stability is caused by a small gap in one hemispherical shell wall (a hemispherical lune) that is successively traversed by the shell's C2 particles. The high pulsation frequency of the captive C2 particles occurs in four phases:

1. Rapid expansion of the captive C2 particles to the outer electron diameter, $d_{eo}$
2. Rapid contraction of the captive C2 particles to the inner electron diameter, $d_{ei}$
3. Accumulation of hyperluminal C1's in the peripheral space of the fully contracted, rotating C2 shell
4. Actuation of the next cycle expansion due to the realization of the critical C1 interference number density in the C2 shell peripheral space

This process is actually the separation and transfer of a hyperluminal subpopulation of the C1 particles into the operational space of the pulsating electron. These partitioned hyperluminal particles are the actuating source of the dynamic properties of the electron. This process is reminiscent of the concept of "Maxwell's demon" which was so named by William Thomson (Lord Kelvin) in an article published in *Nature* in 1874[5]. However, in the context of the massless C1 and C2 particles, there are no force, inertia, energy, or thermodynamic properties. Therefore, any mechanism for the separation of the fundamental particles based on speed cannot violate

Newton's second law, which applies only to processes involving structured particles where entropy is a property.

When considering the angular momentum of the electron, the concept of an angular frequency that results in speeds greater than the speed of light has been historically rejected because it violates the special relativity limit. However, in this postulated model, the rotating structure is a shell of C2 particles driven by hyperluminal C1 particles in the C2 peripheral space of the contracted electron. Therefore, the hyperluminal velocities are associated only with the two massless particles. These particles always remain massless during all their interactions and have no limitation on speed. In contrast, the structured electron and proton are limited to the average speed of the C1 and C2 particles which is the speed of light.

The postulated physical model for the proton is also a pulsating shell of C2 particles, one C2 particle thick with the same number of captive C2 particles in the shell as the electron. The pulsation frequency of the proton shell is identical to that of the electron but 180 degrees out of phase. This configuration and frequency gives rise to the equal but opposite elementary charges of the electron and proton. The proton shell is thereby appropriately a positron with a fully contracted diameter equal to that of the electron. However, the proton has a core inside the positron composed of a precise number of C2 particles. The presence of the core prevents the merger of the electron and proton to create a gamma ray. The core also expands during the shell expansion, but to a lesser degree, and it is compressed during the compression and C1 accumulation phases.

**Acquisition of the Property of Mass**

The manner in which the electron, which is composed of a precise number of massless C2 particles, acquires the property of mass is due to the movement of the center of the structure during each pulsation cycle when the structure is subjected to excess C1 impacts from one direction. When a free C2 particle, meaning one not in an electron or proton, experiences a continuous higher C1 collision rate on one side, it will move instantaneously in response to each collision from all sides without any inertial resistance.  However, it will maintain a constant average velocity with no acceleration in the direction opposite to the higher collision rate.

When there is a higher C1 collision rate on one side of a pulsating electron, all the captive C2 particles acquire an additional velocity increment in the direction opposite to the higher collision rate during the electron expansion and contraction phases. Upon full contraction, the electron center will have moved in that same direction. Also this velocity increment will be acquired by all of the C1 particles that interact with the C2's during the accumulation phase. During the next expansion, the expanded C1's and C2's retain this velocity increment so that the electron center retains the increased velocity.

During this expansion phase, the captive C2's acquire the next velocity increment which is once again transferred to the fully contracted assemblage of C1 and C2 particles with a corresponding incremental movement of the electron center from the previous cycle. The ratio of this accumulation of velocity increments to the total elapsed time is the acceleration of the electron. The finite acceleration of this structured group of C2 particles as compared to the infinite acceleration that accompanies a single C1-C2 collision represents the inertial resistance of the structured group. This acceleration is the basis for the definition of two fundamental concepts in the dynamics of structured systems, namely force and mass, as expressed in Newton's second law of motion, F = ma. Therefore, the mass of the electron arises directly from the inertial resistance of an exact number of C2 particles in a structured group responding to C1 particle collisions.

This same process is at work in the proton. However, the excess C1's are also interacting with the C2's in the proton core, reducing the distance that the center moves by the ratio of the number of C2's in the electron and proton. This also reduces the absorbed velocity increment by the same amount. Therefore, the ratio of the acceleration of the proton to the acceleration of the electron is equal to the ratio of the number of C2's in the electron (mass) to the number of C2's in the proton (mass), under the condition that both have the same constant excess of colliding C1 particles from one direction (force).

**Equations for the Geometric Model**

It was indicated above that the mass of the electron arises directly from the inertial resistance of an exact number of C2 particles in a structured group responding to C1 particle collisions. The virtual mass of each C2 particle, $m_{C2}$, is therefore defined as the mass of the electron, $m_e$, divided by the number of C2 particles, $N_{C2e}$, that form the electron structure:

$$m_{C2} = \frac{m_e}{N_{C2e}} \tag{1}$$

It is a virtual mass because the individual C2 particles are always massless, even when they form the electron and proton structures. The concept of mass and its manifestations of force, inertia, energy, and momentum are always associated with structured particles composed of the massless C2 particles.

In like manner, the virtual density of the C2 particle, $\rho_{C2}$, is defined as virtual mass per actual volume, $\frac{\pi}{6} d_{C2}^3$, where $d_{C2}$ is the actual C2 diameter. By substituting for the virtual mass from above, the virtual density may be viewed as representing the ratio of real properties of the electron to a real property of the C2 particle:

$$\rho_{C2} = \frac{6m_e/N_{C2e}}{\pi d_{C2}^3} \tag{2}$$

In this context, the virtual density is the connector between the geometries of the C2 particle, the electron shell, and the proton core. This is expressed in the following three equations that constitute the geometric model:

$$\rho_{C2} = \frac{6m_{C2}}{\pi d_{C2}^3} \tag{3}$$

$$\rho_{C2} = \frac{m_e}{\epsilon_e \pi d_{C2} d_{ei}^2} \tag{4}$$

$$\rho_{C2} = \frac{6m_{pc}}{\epsilon_{pc} \pi d_{pc}^3} \tag{5}$$

The $\epsilon_e$ in Equation (4) is the packing factor for the electron shell which is the fraction of the electron shell occupied by the C2 particles, and the $d_{ei}$ is the postulated fully contracted electron diameter. The packing factor for the proton core in Equation (5) is $\epsilon_{pc}$, and the $d_{pc}$ is the fully contracted proton core diameter. The expression for $\epsilon_{pc}$ is

$$\epsilon_{pc} = \frac{\pi}{3\sqrt{2}} = 0.740480489693 \cdots \qquad (6)$$

This value is the maximum packing factor for spheres[6], which is regarded as the actual value for the C2 particles in the fully compressed proton core.

## Relationships between Fundamental Constants, C1 and C2 Particle Properties, and New Properties of the Electron and Proton

The premise of this analysis is that the properties of the postulated massless C1 and C2 particles and additional properties of the electron and proton are implicit in the established fundamental constants when combined with the descriptive geometric relations. The determination and evaluation of these properties and the development of their relationships to the fundamental constants were pursued in the following steps:

1. Calculation of the electron shell fully contracted diameter, $d_{ei}$, from fundamental constants
2. Calculation of properties of the C2 particle, electron, and proton from the equations of the geometric model
3. Reduction of uncertainties of these properties by dimensional analysis of fundamental constants
4. Development of expressions for the fundamental constants in terms of the C1, C2, electron, and proton properties
5. Determination of exact values of some fundamental constants and properties

## Calculation of the Electron Shell Fully Contracted Diameter, $d_{ei}$, from Fundamental Constants

With the geometric model specified, the development begins with the dimensional analysis of the equations for the fine structure constant, α, the elementary charge, e, and the Rydberg constant, $R_\infty$, in terms of the Planck constant, h, the electron mass, $m_e$, the speed of light, c, the electric constant, $\epsilon_o$, and the postulated fully contracted electron diameter, $d_{ei}$. The resulting equations are

$$\alpha = \frac{\pi^2}{\sqrt{2}} \frac{m_e c d_{ei}}{h} \qquad (7)$$

$$e = \left[(\sqrt{2}\pi^2 m_e c^2 \epsilon_o d_{ei})\right]^{1/2} \qquad (8)$$

$$R_\infty = \frac{\pi^4}{4} \frac{m_e^3 c^3 d_{ei}^2}{h^3} \qquad (9)$$

Solving each of these equations for $d_{ei}$ using the NIST 2010 CODATA values[3] for all other terms gives the same value of $d_{ei}$ = 2.537037654(55) x $10^{-15}$ m. The lowest uncertainty is obtained by combining Equations (8) and (9) to obtain

$$d_{ei} = \frac{\alpha^3}{\sqrt{2}\pi^2 R_\infty} = 2.5370376541(25) x\ 10^{-15}\ m \quad (10)$$

This value has a relative standard uncertainty of $9.9\ x\ 10^{-10}\ m$ . This result suggests that $d_{ei}$ is a fundamental length consistent with the other fundamental constants α, e, $R_\infty$, h, $m_e$, and c. The postulated model specifies that the positron shell of the proton is equal in size to the electron shell so that the fully contracted proton shell diameter is $d_{pi}$ = $d_{ei}$. Also, the observation that this fully contracted electron diameter has not been measured may be because it is only one C2 diameter thick and only exists in the fully contracted state for a brief time.

**Calculation of Properties of the C2 Particle, Electron, and Proton from the Equations of the Geometric Model**

With a calculated value for $d_{ei}$, approximations for additional fundamental properties are obtained from the geometric model equations. An approximation for Equation (5) based on the accepted equation for the diameter of the atomic nucleus[4] is utilized for the first approximation of $\rho_{C2}$:

$$\rho_{C2} \approx \frac{6m_{pc}}{\epsilon_{pc}^2 \pi (2.4x10^{-15})^3} \quad (11)$$

The result is $\rho_{C2} \approx 4.2121\ x\ 10^{17}\ kg/m^3$ where the mass of the proton core is

$$m_{pc} = m_p - m_e = 1.671710839(74) x\ 10^{-27}\ kg \quad (12)$$

Equation (5) is then solved for the approximate value of $d_{pc}$ to obtain $d_{pc} \approx 2.1713\ x\ 10^{-15}\ m$. With $\epsilon_e$ approximated as the average of hexagonal and cubic packing, $\epsilon_e \approx 0.5641$, Equation (4) is solved to obtain an approximate value of $d_{C2} \approx 1.896\ x\ 10^{-19}\ m$. Equation (3) is then solved to obtain the approximate value $m_{C2} \approx 1.503\ x\ 10^{-39}\ kg$.

**Reduction of Uncertainties of Properties by Dimensional Analysis of Fundamental Constants**

It is assumed, consistent with the above postulates, that the experimentally determined angular momentum of the electron is produced by the actual rotation of the electron and is given by

$$\frac{h}{4\pi} = I\omega \quad (13)$$

The h is the Planck constant, and the terms I and $\omega$ in the product I$\omega$ are regarded here as symbolic only. The classical expression for the moment of inertia, $I = m_e d_{ei}^2/6$, is used as a strategy for determining the actual product terms. If the actual product is written as $I_e\omega_e$ where $I_e$ is the actual electron moment of inertia and $\omega_e$ is the actual electron angular frequency, then

$$h = 4\pi I\omega = 4\pi I_e \omega_e \quad (14)$$

The expression for the universal gravitational constant may be written as

$$G = \frac{\pi\, c^5}{\eta^2 (I\omega)\omega^2} = \frac{\pi\, c^5}{(I_e\omega_e)\omega_e^2} \tag{15}$$

The $\omega_e$ is often called the Planck angular frequency and the right side expression is obtained from its definition in rad/s, defined in terms of h, G, and c as $\omega_e = 2\pi\sqrt{c^5/hG}$. The left side equality requires that $\eta\omega = \omega_e$ where the dimensionless coefficient $\eta$ is evaluated by solving the left side of the equation to obtain

$$\eta = \left[\frac{64\pi^4 I^2 c^5}{Gh^3}\right]^{1/2} = 8.61710(52)x\ 10^{17} \tag{16}$$

The analytic expression for $\eta$ is determined by trial and error to be

$$\eta = \frac{9}{4}\frac{m_e^2}{m_{C2}^2} \tag{17}$$

The value of $m_{C2}$ from this relation is $m_{C2} = 1.471972(44)\ x\ 10^{-39}$ kg. This is within 2 percent of the approximate value obtained for $m_{C2}$ from the geometric model above. Using the improved value of $m_{C2}$ , the other approximate values of the fundamental properties can also be improved. Equating Equations (3) and (4) and solving for $d_{C2}$, the improved value becomes $d_{C2} = 1.8762\ x\ 10^{-19}\ m$ . The value of $\rho_{C2}$ is calculated from Equation (4) as $\rho_{C2} = 4.2566\ x\ 10^{17}\ kg/m^3$ . The value of $d_{pc}$ is calculated from Equation (5) as $d_{pc} = 2.1637\ x\ 10^{-15}\ m$ .

Substituting Equations (14) and (15) into the definitions of the defined Planck parameters yields equations in terms of $I$, $\omega$, $c$, and $\eta$ and equivalent expressions in terms of $I_e$, $\omega_e$, and $c$. These equations calculate the values of the parameters to within the NIST 2010 CODATA uncertainties[3]. All of the Planck parameters in this study are defined in terms of the Planck constant instead of the reduced Planck constant. The Planck mass, $m_{PL}$; mass energy equivalent, $E_{PL}$; length, $L_{PL}$; time, $t_{PL}$; and angular frequency, $\omega_{PL}$; are

$$m_{PL} = \sqrt{hc/G} = \frac{2\eta I\omega^2}{c^2} = \frac{2I_e\omega_e^2}{c^2} \tag{18}$$

$$E_{PL} = \sqrt{hc^5/G} = m_{PL}c^2 = 2\eta I\omega^2 = 2I_e\omega_e^2 \tag{19}$$

$$L_{PL} = \sqrt{hG/c^3} = \frac{2\pi c}{\eta\omega} = \frac{2\pi c}{\omega_e} \tag{20}$$

$$t_{PL} = \sqrt{hG/c^5} = \frac{2\pi}{\eta\omega} = \frac{2\pi}{\omega_e} \tag{21}$$

$$\omega_{PL} = 2\pi\sqrt{c^5/hG} = \eta\omega = \omega_e \tag{22}$$

A relationship between $m_{C2}$ and $d_{ei}$ emerges from the combination of Equations (14), (17), and (20):

$$m_{C2}^2 d_{ei}^2 = \frac{27}{16}\frac{L_{PL}hm_e}{\pi^2 c} \tag{23}$$

It is also noted from Equation (1) that the ratio ${m_e}/{m_{C2}}$ in Equation (17) is the number of C2 particles in the electron shell, $N_{C2e}$. This number is expected to be central to the physical mechanism for the inertia and gravity forces since it is central to the formation of the electron and proton structures which are the cause of inertial resistance as discussed above. The $N_{C2e}$ can now be calculated as

$$N_{C2e} = \frac{m_e}{m_{C2}} = 6.18856(19) x\ 10^8 \tag{24}$$

The number of C2 particles in the proton is calculated as

$$N_{C2p} = \frac{m_p}{m_e} N_{C2e} = 1.136314(35) x\ 10^{12} \tag{25}$$

The number of C2 particles in the proton core is then calculated as

$$N_{C2pc} = N_{C2p} - N_{C2e} = 1.135695(35) x\ 10^{12} \tag{26}$$

**Development of Expressions for the Fundamental Constants in Terms of the C1, C2, Electron, and Proton Properties**

It was found that the dimensional analysis of the fundamental constants in terms of these new properties resulted in equations that accurately calculate the values of the constants and the values of the defined Planck parameters. The equations that emerge for the universal gravitational constant and the Planck constant are

$$G = \frac{1}{\sqrt{3}} \frac{c^2}{n_{C1} d_{C2}^2 m_{C2}} \tag{27}$$

$$h = \sqrt{3}\, n_{C1}^{1/3} d_{C2}^2 m_{C2} c \tag{28}$$

The $n_{C1}$ in these expressions is the inverse cube of the Planck length. It emerges from the dimensional analysis of G, h, α, $R_\infty$ and the defined Planck parameters. In the context of the postulated physical model, it is taken to be the number density of the C1 particles. Equations (27) and (28) are satisfied to within the uncertainties when

$$n_{C1} = L_{PL}^{-3} = 1.50399(27)\ x\ 10^{103}\ \#/m^3 \tag{29}$$

Either Equation (27) or (28) may be used to establish the uncertainty of $d_{C2}$. The improved value is $d_{C2} = 1.874044(28)\ x\ 10^{-19}\ m$ . The improved value of $\rho_{C2}$ is calculated from Equation (3) to obtain $\rho_{C2} = 4.27131(71)\ x\ 10^{17}\ kg/m^3$ . The improved value of $d_{pc}$ is calculated from Equation (5) to obtain $d_{pc} = 2.16120(12)\ x\ 10^{-15}\ m$ .

Again using dimensional analysis, the other fundamental constants are expressed in terms of the new properties. The equations that emerge for the fine structure constant, the elementary charge, and Rydberg constant, respectively, are

$$\alpha = \frac{\alpha_1}{n_{C1}^{1/3} d_{C2}} \tag{30}$$

$$where \quad \alpha_1 = \frac{\pi^2}{\sqrt{6}} N_{C2e} \sqrt{\frac{N_{C2e}}{6\epsilon_e}} \tag{31}$$

$$e = e_1 [2\pi\epsilon_o m_{C2} c^2 d_{C2}]^{1/2} \tag{32}$$

$$where \quad e_1 = \left[\frac{\pi}{\sqrt{2}} N_{C2e} \sqrt{\frac{N_{C2e}}{6\epsilon_e}}\right]^{1/2} \tag{33}$$

$$R_\infty = \frac{R_{\infty 1}}{n_{C1} d_{C2}^4} \tag{34}$$

$$where \quad R_{\infty 1} = \frac{\pi^4}{12\sqrt{3}} N_{C2e}^3 \frac{N_{C2e}}{6\epsilon_e} \tag{35}$$

In Equation (32) the $\varepsilon_o$ is the electric constant (permittivity of free space) having the value $\varepsilon_o = 10^7 / (4 \pi c^2)$.

Using Equations (27) and (28), the defined Planck parameters are now expressed in terms of the diameter and virtual mass of the C2 particle, the number density of the C1 particle, and the speed of light to within the NIST 2010 CODATA uncertainties[3].

$$m_{PL} = \sqrt{hc/G} = \sqrt{3}\, n_{C1}^{2/3} d_{C2}^2 m_{C2} \tag{36}$$

$$E_{PL} = \sqrt{hc^5/G} = \sqrt{3}\, n_{C1}^{2/3} d_{C2}^2 m_{C2} c^2 \tag{37}$$

$$L_{PL} = \sqrt{hG/c^3} = s_{C1} = n_{C1}^{-1/3} \tag{38}$$

$$t_{PL} = \sqrt{hG/c^5} = \frac{L_{PL}}{c} = \frac{n_{C1}^{-1/3}}{c} \tag{39}$$

$$\omega_{PL} = \omega_e = 2\pi\sqrt{c^5/hG} .= 2\pi n_{C1}^{1/3} c \tag{40}$$

The $s_{C1}$ in Equation (38) is physically the average spacing of the C1 particles which is a fundamental length, and it is equal to the Planck length as shown.

The electron moment of inertia becomes $I_e = \frac{\sqrt{3}}{8\pi^2} d_{C2}^2 m_{C2} = \frac{d_{C2}^2 m_{C2}}{81\, \epsilon_e}$ . (41)

An exact expression for the electron shell packing factor, $\epsilon_e$, results from the utilization of these new relationships. Equations (3) and (4) are first combined to obtain

$$m_{C2} d_{ei}^2 = \frac{m_e d_{c2}^2}{6\epsilon_e} \tag{42}$$

This equation is then combined with Equations (23), (28), and (38) to obtain, after cancellation of terms

$$\epsilon_e = \frac{8\pi^2}{81\sqrt{3}} = 0.562787037803 \cdots \tag{43}$$

Parameters related to the electron and proton that are expressed in terms of combinations of G, h, α, e, $R_\infty$, $m_e$, $m_p$, or c can also be accurately expressed in terms of six of the new properties and the speed of light. This is illustrated by the following four representative examples:

The electron Compton wavelength is $\lambda_{Ce} = \frac{h}{m_e c} = \frac{\sqrt{3}}{N_{C2e}} n_{C1}^{1/3} d_{C2}^2$. (44)

The proton Compton wavelength is $\lambda_{Cp} = \frac{h}{m_p c} = \frac{\sqrt{3}}{N_{C2p}} n_{C1}^{1/3} d_{C2}^2$. (45)

The Bohr magneton is $\mu_B = \frac{eh}{4\pi m_e} = \sqrt{\frac{3\epsilon_o}{2\pi}} \frac{e_1}{2N_{C2e}} n_{C1}^{1/3} d_{C2}^{5/2} m_{C2}^{1/2} c^2$. (46)

The magnetic flux quantum is $\phi_o = \frac{h}{e} = \sqrt{\frac{3}{8\pi\epsilon_o}} \frac{1}{e_1} n_{C1}^{1/3} d_{C2}^{3/2} m_{C2}^{1/2}$. (47)

**Determination of Exact Values of Some Fundamental Constants and Properties**

It was observed that the ratio of the total volume of the proton to the volume of the proton core is equal to the golden ratio. The total volume of the proton is

$$Vol_p = \frac{\pi}{6}(d_{ei} + d_{C2})^3 \quad (48)$$

The $d_{C2}$ appears in the equation because the form of Equation (4) implicitly defines the diameter of the fully contracted electron and positron shells to be measured to the centerline of the shell. The volume of the proton core is

$$Vol_{pc} = \frac{\pi}{6} d_{pc}^3 \quad (49)$$

The ratio of the volumes is

$$\frac{Vol_p}{Vol_{pc}} = \left(\frac{d_{ei}+d_{C2}}{d_{pc}}\right)^3 = 1.61805(27) \quad (50)$$

The golden ratio is exact and given by

$$\varphi = \frac{1+\sqrt{5}}{2} = 1.6180339887\cdots \quad (51)$$

These numbers are the same within the calculated uncertainty. The golden ratio also requires that the following equation be equal to $\varphi$.

$$\frac{Vol_{pc}}{Vol_p - Vol_{pc}} = \frac{d_{pc}^3}{(d_{ei}+d_{C2})^3 - d_{pc}^3} = 1.61799(71) \quad (52)$$

Again, the value is equal to the golden ratio within the calculated uncertainty.

The equivalence of these proton volume ratios to the golden ratio has emerged from the traditional fundamental constants in combination with a compatible model of the postulated physical mechanisms of the electron and proton. The resulting specification of these ratios as exactly equal to the golden ratio provides the equations for determining the exact number of C2 particles in the proton and electron shells and the proton core. These exact numbers led to further reductions in the uncertainties of the calculations of the universal gravitational constant, the defined Planck parameters, and most of the values for the properties of the C1 and C2 particles and new properties of the electron and proton. The calculation of the proton-electron ratio became exact.

The equations for the volume ratios can be combined to obtain

$$\varphi = \left(\frac{d_{ei}+d_{C2}}{d_{pc}}\right)^3 = \frac{d_{pc}^3}{(d_{ei}+d_{C2})^3-d_{pc}^3} \tag{53}$$

This equation can be written in terms of the number of C2 particles in the proton core, $N_{C2pc}$, and the electron and positron shells, $N_{C2e}$, by using Equations (1), (3), (4), and (5) to obtain

$$N_{C2e} = \frac{m_e}{m_{C2}} = 6\epsilon_e \frac{d_{ei}^2}{d_{C2}^2} \tag{54}$$

$$N_{C2pc} = \frac{m_{pc}}{m_{C2}} = \epsilon_{pc} \frac{d_{pc}^3}{d_{C2}^3} \tag{55}$$

The ratio of proton volumes becomes

$$\varphi = \frac{\left(\sqrt{\frac{N_{C2e}}{6\epsilon_e}}+1\right)^3}{\left(\frac{N_{C2pc}}{\epsilon_{pc}}\right)} = \frac{\left(\frac{N_{C2pc}}{\epsilon_{pc}}\right)}{\left(\sqrt{\frac{N_{C2e}}{6\epsilon_e}}+1\right)^3-\left(\frac{N_{C2pc}}{\epsilon_{pc}}\right)} \tag{56}$$

The relationship between $N_{C2e}$ and $N_{C2pc}$ is therefore

$$\left(\sqrt{\frac{N_{C2e}}{6\epsilon_e}}+1\right)^3 = \varphi \frac{N_{C2pc}}{\epsilon_{pc}} \tag{57}$$

A second relationship is found using the proton-electron mass ratio. The NIST 2010 CODATA value[3] is

$$A = \frac{m_p}{m_e} = 1836.15267245(75) \tag{58}$$

This is also written as

$$A = \frac{m_p}{m_e} = \frac{m_{pc}+m_e}{m_e} = \frac{N_{C2pc}+N_{C2e}}{N_{C2e}} = \frac{N_{C2pc}}{N_{C2e}} + 1 \tag{59}$$

The second relationship becomes

$$N_{C2pc} = (A-1)N_{C2e} \tag{60}$$

The two relationships, Equations (57) and (60), are combined to obtain

$$\left(\sqrt{\frac{N_{C2e}}{6\epsilon_e}}+1\right)^3 = \varphi \frac{N_{C2e}}{\epsilon_{pc}}(A-1) \tag{61}$$

The solution for $N_{C2e}$ is found by iteration

$$N_{C2e} = 618{,}850{,}827.26(51) \tag{62}$$

The relative standard uncertainty is 8.1 x $10^{-10}$. Since $N_{C2e}$ is an integer with an uncertainty of $\pm$ 0.51, the integer value is taken to be exact

$$N_{C2e} = 618{,}850{,}827 \tag{63}$$

The exact value of $N_{C2pc}$ is calculated from Equation (57) to be

$$N_{C2pc} = 1.135685748775\ x\ 10^{12} \tag{64}$$

The total number of C2 particles in the proton is

$$N_{C2p} = N_{C2pc} + N_{C2e} = 1.136304599602\ x\ 10^{12} \tag{65}$$

Using these exact values for $N_{C2e}$ and $N_{C2p}$, the exact value for the proton-electron ratio is calculated as

$$\frac{m_p}{m_e} = \frac{N_{C2p}}{N_{C2e}} = 1836.15267205905 \cdots \tag{66}$$

The NIST 2010 CODATA value[3] is 1836.15267245(75).

The following parameters are also determined exactly:

$$\eta = \frac{9}{4} N_{C2e}^2 = 8.61696778676814 \cdots x\ 10^{17} \tag{67}$$

$$\frac{d_{ei}}{d_{C2}} = \sqrt{\frac{N_{C2e}}{6\epsilon_e}} = 13{,}537.7135224469 \cdots \tag{68}$$

$$\alpha_1 = \frac{\pi^2}{\sqrt{6}} N_{C2e} \sqrt{\frac{N_{C2e}}{6\epsilon_e}} = 3.37563448871192 \cdots x\ 10^{13} \tag{69}$$

$$e_1 = \left[\frac{\pi}{\sqrt{2}} N_{C2e} \sqrt{\frac{N_{C2e}}{6\epsilon_e}}\right]^{1/2} = 4{,}314{,}029.24655043 \cdots \tag{70}$$

$$R_{\infty 1} = \frac{\pi^4}{12\sqrt{3}} N_{C2e}^3 \frac{N_{C2e}}{6\epsilon_e} = 2.03566440811048 \cdots x\ 10^{35} \tag{71}$$

These exact parameters are used to further reduce the uncertainties of the properties of the massless particles as follows:

$$n_{C1} = L_{PL}^{-3} = 1.5039225708(60) x\ 10^{103}\ \#/m^3 \tag{72}$$

$$s_{C1} = L_{PL} = \frac{\alpha d_{C2}}{\alpha_1} = 4.0512729809(54) x\ 10^{-35}\ m \tag{73}$$

$$d_{C2} = d_{ei} / \sqrt{\frac{N_{C2e}}{6\epsilon_e}} = 1.8740518108(19)\ x\ 10^{-19}\ m \tag{74}$$

$$m_{C2} = \frac{m_e}{N_{C2e}} = 1.471983637(65)\, x\, 10^{-39}\, kg \quad (75)$$

$$\rho_{C2} = \frac{6m_{C2}}{\pi d_{C2}^3} = 4.27129512(20) x\, 10^{17}\ \ kg/m^3 \quad (76)$$

$$d_{pc} = d_{C2}\left(\frac{N_{C2pc}}{\epsilon_{pc}}\right)^{1/3} = 2.1612073974(21) x 10^{-15}\, m \quad (77)$$

The universal gravitational constant is now calculated with a reduced uncertainty as

$$G = \frac{1}{\sqrt{3}}\frac{c^2}{n_{C1}d_{C2}^2 m_{C2}} = 6.67404502(33) x\, 10^{-11}\ \ m^3/kg\, s^2 \quad (78)$$

The relative standard uncertainty is 5.0 x $10^{-8}$. This adds 3 digits to the NIST 2010 CODATA[3] of $G = 6.67384(80) x\, 10^{-11}\ \ m^3/kg\, s^2$ with a relative standard uncertainty of 1.2 x $10^{-4}$.

The other fundamental constants are also calculated from the new properties as follows:

The Planck constant is

$$h = \sqrt{3}\, n_{C1}^{1/3} d_{C2}^2 m_{C2} c = 6.62606958(31) x\, 10^{-34}\ \ kg\, m^2/s \quad (79)$$

The NIST 2010 CODATA value[3] is $h = 6.62606957(29) x\, 10^{-34}\ \ kg\, m^2/s$.

The fine structure constant is

$$\alpha = \frac{\alpha_1}{n_{C1}^{1/3} d_{C2}} = 7.297352570(17) x\, 10^{-3} \quad (80)$$

The NIST 2010 CODATA value[3] is $\alpha = 7.2973525698(24) x\, 10^{-3}$

The elementary charge is

$$e = e_1[2\pi\epsilon_o m_{C2} c^2 d_{C2}]^{1/2} = 1.602176565(36) x\, 10^{-19}\, C \quad (81)$$

The NIST 2010 CODATA value[3] is $e = 1.602176565(35) x\, 10^{-19}\, C$.

The Rydberg constant is

$$R_\infty = R_{\infty 1} n_{C1}^{-1} d_{C2}^{-4} = 10{,}973{,}731.568(88)\, m^{-1} \quad (82)$$

The NIST 2010 CODATA value[3] is $R_\infty = 10{,}973{,}731.568539(55)\, m^{-1}$.

The mass of the electron is

$$m_e = m_{C2} N_{C2e} = 9.10938291(40) x\, 10^{-31}\, kg \quad (83)$$

The NIST 2010 CODATA value[3] is $m_e = 9.10938291(40) x\, 10^{-31}\, kg$.

The mass of the proton is

$$m_p = m_{C2} N_{C2p} = 1.672621777(74) x\, 10^{-27}\, kg \quad (84)$$

The NIST 2010 CODATA value[3] is $m_p = 1.672621777(74) x\, 10^{-27}\, kg$.

The uncertainty of each of the five derived Planck parameters listed above has been reduced as follows:

The Planck mass is

$$m_{PL} = \sqrt{3}\, n_{C1}^{2/3} d_{C2}^2 m_{C2} = 5.45561583(27) x\, 10^{-8}\, kg. \tag{85}$$

This adds 3 digits to the NIST 2010 CODATA value[3] of $m_{PL} = 5.45570(33) x\, 10^{-8}\, kg$.

The Planck mass energy equivalent is

$$E_{PL} = \sqrt{3}\, n_{C1}^{2/3} d_{C2}^2 m_{C2} c^2 = 4.90326298(24) x\, 10^{9}\, J \tag{86}$$

This adds 3 digits to the NIST 2010 CODATA value[3] of $E_{PL} = 4.90334(30) x\, 10^{9}\, J$.

The Planck length is

$$L_{PL} = n_{C1}^{-1/3} = \frac{\alpha d_{C2}}{\alpha_1} = 4.0512729809(54) x\, 10^{-35}\, m. \tag{87}$$

This adds 5 digits to the NIST 2010 CODATA value[3] of $L_{PL} = 4.05121(24) x\, 10^{-35}\, m$.

The Planck time is

$$t_{PL} = \frac{1}{c n_{C1}^{1/3}} = \frac{\alpha d_{C2}}{c \alpha_1} = 1.3513592063(18) x\, 10^{-43}\, s. \tag{88}$$

This adds 4 digits to the NIST 2010 CODATA value[3] of $t_{PL} = 1.351338(80) x\, 10^{-43}\, s$.

The Planck angular frequency is

$$\omega_{PL} = \omega_e = 2\pi n_{C1}^{1/3} c = 4.6495301013(62) x\, 10^{43}\, {}^{rad}/_{s} \tag{89}$$

This adds 5 digits to the currently accepted value of $\omega_{PL} = 4.64960(28) x\, 10^{43}\, {}^{rad}/_{s}$.

The $\alpha_1, e_1, and\ R_{\infty 1}$ are exact values given by Equations (69), (70), and (71), respectively.

## Calculation of Other Electron Properties and Related Parameters

The new properties are also utilized to calculate the values of known parameters associated with functional characteristics of the electron. Likewise, potential additional properties of the electron suggestive of a different interpretation of some experimental results are calculated. An example is the interpretation of the electron moment of inertia and angular frequency in relation to the angular momentum.

The electron moment of inertia is $I_e = \frac{d_{C2}^2 m_{C2}}{81\, \epsilon_e} = 1.134062694(52) x\, 10^{-78}\, kg\, m^2$. (90)

In the postulated model, this value is regarded as the actual electron moment of inertia in the fully contracted state. Its value is not considered to be a function of the mass of the electron which results from inertial resistance to linear displacement of the center of the electron structure. By contrast, the moment of inertia is a result of inertial resistance to angular displacement of the center of the electron structure. This small angular displacement is likely produced by the kinematic asymmetry resulting from the small gap in one hemispherical shell wall (a hemispherical lune) that causes the electron rotation. The rotational motion of the massless C2 particles is not influenced by the resistance to linear displacement of the C2 particle structure. Therefore, the electron moment of inertia is not a function of the electron mass.

The other term in the electron angular momentum is the Planck angular frequency (Equation 89) which is taken to be the actual electron angular frequency, $\omega_e$. The average hyperluminal speed of the segregated C1 particles in the electron interior can then be calculated as

$$V_{C1HL} = \frac{d_{ei}\omega_e}{2} = \pi\sqrt{\frac{N_{C2e}}{6\epsilon_e}}\, n_{C1}^{1/3} d_{C2} c = 5.898016470(14)x\ 10^{28}\ m/_s \qquad (91)$$

As discussed above, speeds of this large magnitude are not prohibited for the massless particles as only their average speed is required to be the speed of light. This is feasible as demonstrated by the following example. Consider that the subluminal subpopulation has a number density of $n_{C1}$ and an average velocity of c/2, and the hyperluminal subpopulation has a number density of $n_{C1HL}$ and a velocity of $V_{C1HL}$. For this case the collision frequencies of the C1 particle subpopulations with a single C2 particle are equal. From kinetic theory[7] the relationship between the average velocities and number densities is $n_{C1}(c/2) = n_{C1HL}V_{C1HL}$. This equation is solved for $n_{C1HL} = 3.822171797(24)x\ 10^{82}\ \#/m^3$. The hyperluminal subpopulation number density is large but negligible compared to $n_{C1} = 1.5039225708(60)x\ 10^{103}\ \#/m^3$. The average speed of the total population is $V_{avg} = \frac{n_{C1}\,(c/_2) + n_{C1HL}\,(V_{C1HL})}{n_{C1} + n_{C1HL}} = \frac{2n_{C1}\,(c/_2)}{n_{C1}} = c$. The conclusion is that a massless particle population can have an average speed of c and also have a hyperluminal subpopulation. These calculations suggest that the electron may be a condition where the speed distribution of the massless C1 particles is utilized to repetitively assemble and disassemble a stable structure composed of massless C2 particles.

**Development of Ratios of Electrostatic Force to Gravitational Force in Terms of New Properties**

The ratios of the electrostatic force to the gravitational force between two electrons, two protons, and an electron and a proton are developed in terms of the new properties.

When Coulomb's law for the electrostatic force is nondimensionalized using the new properties, the equation becomes

$$F_{ES}^* = \kappa^* \frac{q_1^* q_2^*}{(r^*)^2} \qquad (92)$$

The nondimensional terms are denoted by an asterisk. The force is $F_{ES}^* = F_{ES}\frac{d_{C2}}{m_{C2}c^2}$; the Coulomb constant is $\kappa^* = \frac{\kappa e^2}{m_{C2}c^2 d_{C2}} = \frac{e_1^2}{2}$; the charge is $q^* = \frac{q}{e}$; and the distance is $r^* = \frac{r}{d_{C2}}$.

When Newton's law of universal gravitation is nondimensionalized using the new properties, the equation becomes

$$F_G^* = \mathrm{G}\frac{m_1^* m_2^*}{(r^*)^2} \tag{93}$$

The force is $F_G^* = F_G \frac{d_{C2}}{m_{C2}c^2}$; the universal gravitational constant is $G^* = \frac{Gm_{C2}}{c^2 d_{C2}} = \frac{1}{\sqrt{3}n_{C1}d_{C2}^3}$; the mass is $m^* = \frac{m}{m_{C2}}$; and the distance is $r^* = \frac{r}{d_{C2}}$ .

The ratio of the electrostatic force to the gravitational force between two electrons is

$$\frac{F_{ES}}{F_G} = \frac{F_{ES}^*}{F_G^*} = \frac{\kappa^*}{G^*}N_{C2e}^{-2} = \frac{\sqrt{3}}{2}e_1^2 n_{C1} d_{C2}^3 N_{C2e}^{-2} = 4.165768272(29)x\ 10^{42} \tag{94}$$

This ratio between two protons is

$$\frac{F_{ES}}{F_G} = \frac{F_{ES}^*}{F_G^*} = \frac{\kappa^*}{G^*}N_{C2p}^{-2} = \frac{\sqrt{3}}{2}e_1^2 n_{C1} d_{C2}^3 N_{C2p}^{-2} = 1.2355989477(85)x\ 10^{36} \tag{95}$$

This ratio between an electron and a proton is

$$\frac{F_{ES}}{F_G} = \frac{F_{ES}^*}{F_G^*} = \frac{\kappa^*}{G^*}N_{C2e}^{-1}N_{C2p}^{-1} = \frac{\sqrt{3}}{2}e_1^2 n_{C1} d_{C2}^3 N_{C2e}^{-1}N_{C2p}^{-1} = 2.268748309(16)x\ 10^{39} \tag{96}$$

The relative standard uncertainty for each of these ratios is 7.0 x $10^{-9}$. The new properties produce ratios with lower certainties than the currently accepted values that have relative standard uncertainties of 1.8 x $10^{-7}$.

**Examples of Calculations for Related Parameters**

The calculated values of the four representative electron or proton parameters presented as examples in Equations (44), (45), (46), and (47) produce uncertainties equivalent to the NIST 2010 CODATA values[3] as follows:

The electron Compton wavelength is

$$\lambda_{Ce} = \frac{\sqrt{3}}{N_{C2e}}\ n_{C1}^{1/3} d_{C2}^2 = 2.4263102390(82)x\ 10^{-12}\ m \tag{97}$$

The NIST 2010 CODATA value[3] is $\lambda_{Ce} = 2.4263102389(82)x\ 10^{-12}\ m$.

The proton Compton wavelength is

$$\lambda_{Cp} = \frac{\sqrt{3}}{N_{C2p}}\ n_{C1}^{1/3} d_{C2}^2 = 1.3214098565(45)x\ 10^{-15}\ m \tag{98}$$

The NIST 2010 CODATA value[3] is $\lambda_{Cp} = 1.32140985623(94)x\ 10^{-15}\ m$.

The Bohr magneton is

$$\mu_B = \sqrt{\frac{3\epsilon_o}{2\pi}}\frac{e_1}{2N_{C2e}}\ n_{C1}^{1/3} d_{C2}^{5/2} m_{C2}^{1/2} c^2 = 9.27400968(24)x\ 10^{-24}\ \frac{Cm^2}{s}\ (JT^{-1}) \tag{99}$$

The NIST 2010 CODATA value[3] is $\mu_B = 9.27400968(20)x\ 10^{-24}\ \frac{Cm^2}{s}\ (JT^{-1})$.

The magnetic flux quantum is

$$\phi_o = \sqrt{\frac{3}{8\pi\epsilon_o}}\frac{1}{e_1}\, n_{C1}^{1/3} d_{C2}^{3/2} m_{C2}^{1/2} = 2.067833758(52) x\ 10^{-15}\ Wb\ (\frac{kg\ m^2}{C\ s}) \tag{100}$$

The NIST 2010 CODATA value[3] is $\phi_o = 2.067833758(46) x\ 10^{-15}\ Wb\ (\frac{kg\ m^2}{C\ s})$.

**Additional Functions of the New Properties**

The harmonic vibrational frequency of the C2 particle grid system, $f_{C2}$, in free space is also a function of the C1 and C2 properties. It is observed that the calculated value of $f_{C2}$ is equal to the average frequency of the cosmic microwave background, $\bar{f}_{CMB}$. It is emphasized that this is the average frequency, not the frequency based on peak intensity, which is normally reported.

$$f_{C2} = \bar{f}_{CMB} = \frac{c}{\sqrt{3}\, n_{C1}^{1/3} d_{C2}^2} = \frac{m_{C2} c^2}{h} \tag{101}$$

$$f_{C2} = \bar{f}_{CMB} = 1.9965877232(67) x\ 10^{11}\ Hz \tag{102}$$

The pulsation frequency and period of the electron, respectively, are

$$f_e = \frac{n_{C1}^{1/3} c}{\left(3^{1/4}\right)\pi\left(N_{C2e}^{3/2}\right)} = 1.1625724993(16)\ x\ 10^{29}\ Hz \tag{103}$$

$$T_e = \frac{1}{f_e} = 8.601614098(12) x\ 10^{-30}\ s \tag{104}$$

The average speed of the electron captive C2 particles during expansion and contraction is

$$V_{C2e} = \frac{(3)^{1/4}}{\sqrt{N_{C2e}}} n_{C1}^{1/3} d_{C2} c = 7.336655288(17) x\ 10^{19}\ m/s \tag{105}$$

The outer electron diameter is at full expansion is given by

$$d_{eo} - d_{ei} = \frac{V_{C2e}}{f_e} = \sqrt{3}\pi N_{C2e} d_{C2} = 6.3107077604(64) x\ 10^{-10}\ m \tag{106}$$

$$d_{eo} = 6.3107331308(60) x\ 10^{-10}\ m \tag{107}$$

This harmonic frequency of the C2 grid system is different than the collision frequency of the C1 particles with a single C2 particle in free space which is given by

$$\theta_{C1-C2} = \frac{\pi}{16} n_{C1} d_{C2}^2 c = 3.109132690(12) x\ 10^{73}\ s^{-1} \tag{108}$$

The wavelengths, $\lambda$, for the atomic line spectra are also accurately calculated in terms of the new properties as $\frac{1}{\lambda} = \frac{R_{\infty 1}}{n_{C1} d_{C2}^4} Z^2 \left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$ $where\ n_i, n_f = 1,2,3, \cdots and\ n_i > n_f$ and Z = number of protons.

## Summary

Properties of two postulated fundamental massless particles and new properties of the electron and proton have been identified and evaluated. The approach was to require these properties to satisfy both the equations describing a postulated geometric model and the developed equations for the traditional fundamental constants. The sole claim of this paper is that these new emergent properties satisfy the geometric model and accurately calculate the known values of the fundamental constants. This has been demonstrated as summarized below.

There are twelve new emergent properties as follows:

$$n_{C1} = 1.5039225708(60)x\ 10^{103}\ \ \#/m^3 \qquad (72)$$

$$d_{C2} = 1.8740518108(19)\ x\ 10^{-19}\ m \qquad (74)$$

$$m_{C2} = 1.471983637(65)\ x\ 10^{-39}\ kg \qquad (75)$$

$$N_{C2e} = 618{,}850{,}827 \qquad (63)$$

$$\epsilon_e = \frac{8\pi^2}{81\sqrt{3}} = 0.562787037803\cdots \qquad (43)$$

$$N_{C2pc} = 1.135685748775\ x\ 10^{12} \qquad (64)$$

$$\epsilon_{pc} = \frac{\pi}{3\sqrt{2}} = 0.740480489693\cdots \qquad (6)$$

$$N_{C2p} = 1.136304599602\ x\ 10^{12} \qquad (65)$$

$$d_{pc} = 2.1612073974(21)x10^{-15}\ m \qquad (77)$$

$$m_{pc} = 1.671710839(74)x\ 10^{-27}\ kg \qquad (12)$$

$$\rho_{C2} = 4.27129512(20)x\ 10^{17}\ \ kg/m^3 \qquad (76)$$

$$d_{ei} = 2.5370376541(25)x\ 10^{-15}\ m \qquad (10)$$

These values satisfy the following equations of the geometric model which connects the geometries of the massless C2 particle, the electron, and the proton core.

$$\rho_{C2} = \frac{6m_{C2}}{\pi d_{C2}^3} \qquad (3)$$

$$\rho_{C2} = \frac{m_e}{\epsilon_e \pi d_{C2} d_{ei}^2} \qquad (4)$$

$$\rho_{C2} = \frac{6m_{pc}}{\epsilon_{pc}\pi d_{pc}^3} \qquad (5)$$

The following fundamental constants are expressed in terms of six of the new properties listed above plus the speed of light, and their calculated values have uncertainties that are comparable to or better than the NIST 2010 CODATA values[3].

$$G = \frac{1}{\sqrt{3}} \frac{c^2}{n_{C1} d_{C2}^2 m_{C2}} = 6.67404502(33) x\, 10^{-11}\ m^3/kg\, s^2 \quad (78)$$

$$h = \sqrt{3}\, n_{C1}^{1/3} d_{C2}^2 m_{C2} c = 6.62606958(31) x\, 10^{-34}\ kg\, m^2/s \quad (79)$$

$$\alpha = \frac{\alpha_1}{n_{C1}^{1/3} d_{C2}} = 7.297352575(17) x\, 10^{-3} \quad (80)$$

$$e = e_1 [2\pi \epsilon_o m_{C2} c^2 d_{C2}]^{1/2} = 1.602176565(36) x\, 10^{-19}\, C \quad (81)$$

$$R_\infty = R_{\infty 1} n_{C1}^{-1} d_{C2}^{-4} = 10{,}973{,}731.568(88)\, m^{-1} \quad (82)$$

$$m_e = m_{C2} N_{C2e} = 9.10938291(40) x\, 10^{-31}\, kg \quad (83)$$

$$m_p = m_{C2} N_{C2p} = 1.672621777(74) x\, 10^{-27}\, kg \quad (84)$$

The calculation of the universal gravitational constant is particularly significant in two respects. First, its value is not traditionally determined from the other fundamental constants and must be evaluated solely from experiments. As a result, its value has the largest uncertainty of any of the fundamental constants. The new properties provide the relationships between it and the other constants. Second, the current analysis adds three digits to the NIST 2010 CODATA value[3] bringing it to a relative standard uncertainty consistent with the Planck constant and masses of the electron and proton.

Two of the new properties give an exact value for the proton-electron mass ratio:

$$\frac{m_p}{m_e} = \frac{N_{C2p}}{N_{C2e}} = 1836.15267205905 \cdots \quad (66)$$

In addition, the derived Planck parameters are expressed in terms of the new properties plus the speed of light and calculated with uncertainties that are less than the NIST 2010 CODATA values[3]. Likewise, parameters related to the electron and proton that can be expressed in terms of combinations of G, h, α, e, $R_\infty$, $m_e$, $m_p$, and c can also be accurately expressed in terms of the new properties and the speed of light.

While the objective here is not to prove the existence of a physical electron, the success of this work in linking the fundamental constants, including the universal gravitational constant, to the postulated physical model lays a foundation for further research into the underlying mechanisms.

In that context, this postulated model does offer potential explanations for observed characteristics of the electron. The interactions of the two massless particles result in a pulsating electron shell and a 180 degree out-of-phase pulsating proton shell. This suggests that electrons and protons may not be single particles or pure waves. Instead, they may be captive structured groups of fundamental particles moving in a pulsating wave-like fashion resulting in a wave-particle duality. The outgoing and incoming movement of the C1 particles may be the mechanism for the electrostatic (Coulomb) force resulting in the equal but opposite charges of the electron and proton.

In addition, the hyperluminal subpopulation of the C1 particles provides a possible explanation for the apparently instantaneous transfer rate associated with quantum entanglement[8]. The average hyperluminal speed of the segregated C1 particles in the electron interior given by Equation (91) is sufficiently high to represent instantaneous transfer. This hyperluminal C1 subpopulation could provide causation for the phenomena referred to by Einstein as "spooky action at a distance"[9].

The potential existence of a physical electron and compatible proton would alter the paradigm in an important area of atomic physics. These developed relationships and their numerical agreement with the known values of the fundamental constants provide a basis for further investigation into this possibility.

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