Quantum Electric Gravity

Rad H Dabbaj

United Kingdom
rdabbaj@btinternet.com

Abstract

This paper proposes a new theory of gravity called quantum electric gravity (QEG) based entirely on electromagnetic and quantum electrodynamics (QED) principles. Neutral atoms contain equal amount of absolute positive and negative charge such that they interact by both attractive and repulsive forces. In classical electromagnetism the absolute magnitudes of these forces are exactly and symmetrically identical. However, from a quantum mechanical/QED perspective the picture is subtly different. In QED the electric and magnetic forces are mediated by the exchange of virtual particles and are subject to the quantum mechanical rules of probabilities and Heisenberg Uncertainty principle. Quantum electric gravity introduces an appropriate quantum parameter to classical electromagnetic forces in order to improve compatibility with quantum mechanics. There are compelling observations and experiments to suggest that the quantum parameters for attractive and repulsive forces are not exactly and symmetrically identical. This leads the symmetry to breakdown and leaves a clear non-zero net force synonymous with and indistinguishable from the force of gravity. This asymmetry between forces proved crucial in securing inverse square law in line with Newton's and general relativity. Interestingly, quantum electric gravity theoretically derives the underlying formula for the gravitational "constant" *G* and predicts its nonlinear behaviour at high field intensities. Quantum electric gravity is compatible with quantum mechanics, QED and the special theory of relativity.

Keywords: quantum electric gravity, quantum gravity, new theory of gravity, corrections to gravitational constant, quantum electrodynamics, quantum mechanics, electric gravity, gravity, gravitation, cosmology

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1. Introduction

This paper proposes a new theory of gravity called quantum electric gravity (QEG) based entirely on electromagnetic and quantum electrodynamics (QED) principles. QEG describes a quantum theory of gravity with results substantially in line with Newton's, General Relativity and beyond. Newton's Law of Gravitation (NLG) explains how the universe works, predicts the force of gravity and enables the successful landing on far away planets and moons. Apart from that, it provides no explanations as to the real cause of gravity and suffers from a number of anomalies. General Relativity (GR) upholds NLG and introduces improvements particularly at high field intensities, resolves the anomaly of the perihelion advance of Mercury and predicts a range of other phenomena confirmed by experiments. GR proposes the warping of space-time as the cause of gravity between objects. GR too has its own shortcomings like the problem with infinities and, when dealing with atoms and the realm of the highly successful fundamental theory of Quantum Mechanics (QM), it just completely breaks down [1]. What makes matter even worse is the fact that, hitherto, the nature and origin of gravity continue to be highly illusive and stubbornly incompatible with the other fundamental forces of nature like electromagnetic (EM) and atomic forces. The contemporary crises in physics and cosmology mainly arise from GR's incompatibility with quantum mechanics and the failure of any efforts to unite them

[1,2]. Finding the secrets of gravity and making it compatible with the other fundamental forces of nature is considered as the Holy Grail in physics today.

Among QEG's main objectives was the quantization of the classical Coulomb electric forces between atoms. As it turned out, the opposing attractive and repulsive forces between atoms are not symmetrically identical due to; a) differences in quantum parameters and, b) small relative shift in atomic charge positions that minimises total energy. This gives rise to asymmetric behaviour which leaves a clear non-zero net force synonymous with and indistinguishable from the force of gravity. The asymmetric behaviour proved crucial in securing QEG's inverse square law in line with Newton's and general relativity. QEG sheds some light on the origin, nature and cause of the gravitational parameter G and theoretically derives its quantum electric equivalent, G_{QE}. As described below, the following QEG equation is derived from basic EM and QED principles:

$$\mathbf{F}_{\mathrm{QEG}} = -G_{\mathrm{QE}} \frac{m_1 m_2}{r^2}\, \hat{\mathbf{r}}, \qquad G_{\mathrm{QE}} = \frac{e^2 N_{\mathrm{A}}^2}{2\pi\varepsilon_0} T_{\mathrm{D}} \left(T_{\mathrm{P}} + T_{\delta}\right) \tag{1}$$

In this paper we shall proceed by highlighting the similarities between gravity and EM forces. We use QED to explain the modern views on the concept of action-at-a-distance, force mediation via virtual particles and then establish the QM basis for inverse square law behaviour. We interpret Coulomb's Law in terms of QED's quantum parameters, determine electromagnetic forces between atoms using Dipole Atomic model and propose a new quantum electric coupling mechanism that can be determined from experiments. Using charge-mass relations we can then show how to determine object charge from its mass and eventually arrive at Newton's (NLG) and beyond. We shed some light on the gravitational parameter G and derive its quantum electric formula (G_{QE}). Finally, we summarize the main features of QEG and discuss some of its implications.

2. Gravity and Electromagnetism

The similarities between gravitational and electromagnetic forces make one wonders whether the two can be linked together. Many scientists, including James Clerk Maxwell, pondered about a possible link between the two. In fact Albert Einstein dedicated the second half of his life to a unified field theory in attempt to combine gravity with electromagnetism. Both phenomena share some common attributes such as long-range, their force formulae have similar general form and both follow inverse square law. However, before combining the two forces one must first overcome some major issues, among them:

a) Magnitude – there is an enormous magnitude difference with EM/gravity force ratio ~$1\mathrm{x}10^{40}$!
b) Polarity – gravity is attractive while EM forces can be both attractive and repulsive
c) Mass and charge – gravity interacts with mass while electromagnetism interacts with charge.

As we will see in more details below, QEG can resolve these issues and successfully combine gravity with electromagnetism and quantum mechanics. As charge-dual entities, atoms interact with other atoms via two types of EM forces of almost identical magnitudes; attractive and repulsive. These opposite direction forces largely cancel each other out but leave a clear residue that resolves issues (a) and (b) above. The issue of mass and charge can be resolved because both are quite closely related in the standard model of particle physics. The long-range aspect of both gravity and EM forces is very fundamental and represents the crucial common attribute to the successful combination of their forces, which would not otherwise be possible.

3. Electric and Magnetic Forces

In this section we shall determine the electric and magnetic forces using Coulomb's Law, QED and relevant quantum parameters, the dipole atomic model and atomic charge shift.

3.1. Classical Electromagnetic Forces

Coulomb's Law defines the electric force between two charges q_1, q_2 distance r apart as [3]:

$$\mathbf{F} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\,\hat{\mathbf{r}} \tag{2}$$

The term $1/4\pi\varepsilon_0$ is also referred to as the proportionality constant k, and $\hat{\mathbf{r}}$ is the unit vector. Coulomb's Law describes the interaction between static charges, but for moving charges one needs to include the motion-related magnetic forces [4,5]. The combined total electric and magnetic force $\mathbf{F}_{\mathrm{EM}}$ can be written as follows:

$$\mathbf{F}_{\mathrm{EM}} = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}\,T_{\mathrm{D}}\,\hat{\mathbf{r}} \tag{3}$$

where T_{D} is a generic motion-dependent dynamic factor or term. We shall consider here the tangential T_{D} as shown in Figure 1 as a typical example, comprising a source charge q_1 moving with constant velocity $\mathbf{v}_1$ and a test charge q_2 moving with constant velocity $\mathbf{v}_2$, at distance r apart. Both $\mathbf{v}_1$ and $\mathbf{v}_2$ are along the normal to r and are less than the speed of light c. It does not matter whether q_1 is considered as the source charge and q_2 as the test charge, or vice versa. The tangential term T_{Dt} can be determined using Lorentz Transformations [5] with factor γ, as follows:

$$T_{\mathrm{Dt}} = \gamma\left(1-\frac{\mathbf{v}_1\,\mathbf{v}_2}{c^2}\right) = \left(1+\frac{1}{2}\frac{\mathbf{v}_1^2}{c^2}-\frac{\mathbf{v}_1\,\mathbf{v}_2}{c^2}\cdots\cdots\right), \qquad \gamma = \left(1-\left(\frac{\mathbf{v}_1}{c}\right)^2\right)^{-0.5} \tag{4}$$

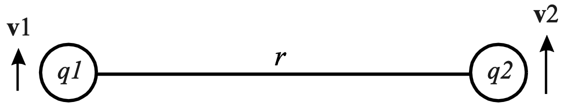

Figure 1 - EM forces between two charges

3.2. Quantum Electrodynamics and EM Forces

Quantum Electrodynamics (QED) considers the EM forces as manifestations of random processes of exchange of messenger or mediator particles in the form of discrete randomly fluctuating virtual particles/photons [6,7,8,9] – see Appendix-A for more details. In QED, virtual photons share some similar properties with real photons including zero mass, travelling at the speed of light and emission in all directions in 3D space, except for the temporary violation of normal energy and momentum considerations in line with the Heisenberg Uncertainty principle. In his book [6], Richard Feynman describes three basic QED actions; 1) a photon goes from place to place, 2) an electron goes from place to place and, 3) an electron emits or absorbs a photon. These actions apply to all structure-less charge particles and photons [7]. Each one of these actions has an amplitude and probability density.

In the quantum vacuum, virtual photons are emitted from a source charge in all directions and their density decays with distance r from source, which in 3D space makes the density follows inverse square law and leads to the Coulomb forces [7,8]. Coulomb's Law represents a statistical average of large number of QED particle interactions. What QEG proposes is to explicitly include an appropriate quantum factor or parameter "P" in (2,3) in order to reflect the probabilistic nature of QM/QED particle interactions and the resulting forces, as follows:

$$\mathbf{F} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\,T_{\mathrm{D}}\,P\,\hat{\mathbf{r}} \tag{5}$$

In general the value of P is expected to be quite close to unity ($P \sim 1$), subject to quantum probabilities and Heisenberg Uncertainty Principle. Quantum parameter P may represent one or more of force-controlling factors, statistical particle-particle interactions, probability or probability density of likelihood of interactions, cross section of particle interactions (e.g. scattering or absorption processes) and others.

The concept of quantum parameter P may strike the reader as superficial but, as we shall see below, this will be quite well supported and justified, so much so it'll prove crucial in securing QEG's inverse square law in line with Newton's and GR. This is because the electric attractive and repulsive forces are two "intrinsically different" kinds of fundamental forces intimately connected to the law of charge conservation. There are good indications and plausible support/experiments for the existence of a kind of quantum asymmetry on an ultra-microscopic level between the quantum parameters for attractive (P_a) and repulsive (P_r) forces such that the difference ($P_a - P_r$) > 0 - see SS-5.3.

3.3. Dipole Atomic Model

Neutral atoms can be considered as charge-dual entities comprising equal absolute magnitude of positive and negative charges - for more details see Appendix-B. For electric force calculations, the atom can be represented by a simple effective electric model, such as the Dipole Atomic model, comprising positive and negative charge as shown in Figure 2. In this model, the positive quarks charge represents the total positive charge $+q$ in the atom, while the combined electron and negative quarks charge represents the total negative charge $-q$ in the atom. From Gauss Law [10], the positive $+q$ and negative $-q$ atomic charges can be treated as point charges located at the centre of their respective entity.

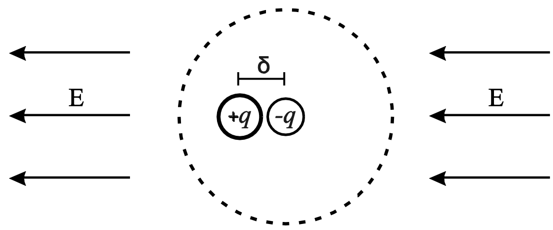

Figure 2 – Atom in Electric Field E (Shift Exaggerated)

The negative and positive atomic charge entities are mutually held together in their relative positions by EM forces. These positions are not rigidly fixed but are rather flexible and can shift ($\boldsymbol{\delta}$) in response to external electric field **E**, e.g. field arising from other atoms. Field **E** causes the centre of the electron cloud to move in one direction while the nucleus moves in the opposite, such that the total shift $\boldsymbol{\delta}$ between centres lies substantially along the field [11,12]. In effect, this phenomenon minimises the total energy of the system by setting up an internally induced electric dipole opposing the original field, the moment of which dipole **p** is given by:

$$\mathbf{p} = q\boldsymbol{\delta} = \alpha \mathbf{E} \qquad (6)$$

where q is the atomic charge and α is a property of atoms known as (deformation) polarizability ($\alpha = 4\pi\varepsilon_0 a^3$) [11,12]. The values of α for various elements can be found in published data [13], e.g. $\alpha_{\text{(Hydrogen)}} \sim 7.419 \times 10^{-41}$ Cm^2/V. Shift $\boldsymbol{\delta}$ depends on ratio α/q and can be determined from (6) as:

$$\boldsymbol{\delta} = \frac{\alpha}{q}\mathbf{E} \qquad (7)$$

Since the external electric field **E** (arising from external atoms/dipoles) varies with distance as $1/r^3$ [14] (see Appendix–C), the shift is expected to vary in a similar manner, i.e. $1/r^3$. One may use alternative more accurate atomic models like that of the Tripole Atomic model – see S-8 point (8).

4. Force between Objects

In this section we shall determine the total electric and magnetic forces between two atoms and then extend this to determine the total force between two larger objects.

4.1. Attractive and Repulsive Forces between Atoms

We now have the following three important phenomena and concepts; a) QED's virtual particle interactions are governed by QM probabilities and the Heisenberg Uncertainty principle (SS-3.2), b) as charge-dual entities, atoms interact via bi-directional attractive and repulsive forces (SS-3.3 and Appendix–B) and, c) the atomic charge position shifts in response to external electric field (SS-3.3). One can make use of these concepts to determine the EM force between two atoms as a typical example in the analyses below, and later extend this to the force between objects. Figure 3 shows two neutral atoms 1 and 2 separated by distance r. Atom 1 comprises positive charge $+q_1$ and negative charge $-q_1$ and atom 2 comprises positive charge $+q_2$ and negative charge $-q_2$. Atoms 1 and 2 undergo induced shifts $\boldsymbol{\delta}_1$, $\boldsymbol{\delta}_2$, respectively, due to their interactions with each other's electric field. For completeness, we also assume that atom 1, 2 are moving at constant velocities $\mathbf{v}_1$ and $\mathbf{v}_2$ as in the case of Figure 1, respectively. The distance r between nuclei was taken as the effective distance between the atoms.

The atomic charge shift includes the time-averaged vector sum of shifts arising from all other atoms whether internal or external to the object, all superposed together. The 3D shift analysis and calculations are rather involved and quite complicated, and falls outside the scope of this paper. However, in order to simplify the analysis, we shall consider the configuration shown in Figure 3 as a typical approximate example serving to illustrate the basic concept behind atomic charge shift and how it can influence electrical forces between atoms.

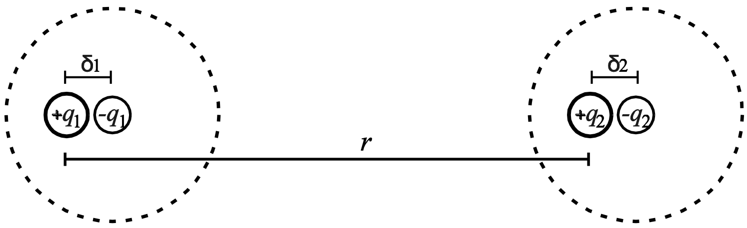

Figure 3 – Electrical Interaction between Two Atoms

In quantum electric gravity it is instructive to express the total EM force as the sum of two separate main components, namely that of the attractive component ($\mathbf{F}_{\text{att}}$) and that of the repulsive component ($\mathbf{F}_{\text{rep}}$). This way, the true concept and working mechanism of QEG can be accurately portrayed as that force arising from the constant battle between these two giant forces that, when combined, leave a clear *residue* that one perceives as gravity.

The total attractive and repulsive EM forces between atom 1 and 2 can be determined using (5) by adding all corresponding attractive and repulsive components. Since there are four charge entities in Figure 3 ($+q_1$, $-q_1$, $+q_2$, $-q_2$), there is a total of four interatomic force components, two attractive and two repulsive, as follows:

$$\mathbf{F}_{\text{att}} = \frac{1}{4\pi\varepsilon_0}\left(\frac{(-q_1)(+q_2)}{(r-\boldsymbol{\delta}_1)^2}\,T_{\text{D}}\,P_{\text{a}} + \frac{(+q_1)(-q_2)}{(r+\boldsymbol{\delta}_2)^2}\,T_{\text{D}}\,P_{\text{a}}\right)\hat{\mathbf{r}} \tag{8}$$

$$\mathbf{F}_{\text{rep}} = \frac{1}{4\pi\varepsilon_0}\left(\frac{(+q_1)(+q_2)}{r^2}\,T_{\text{D}}\,P_{\text{r}} + \frac{(-q_1)(-q_2)}{(r-\boldsymbol{\delta}_1+\boldsymbol{\delta}_2)^2}\,T_{\text{D}}\,P_{\text{r}}\right)\hat{\mathbf{r}} \tag{9}$$

Note that forces $\mathbf{F}_{\text{att}}$ and $\mathbf{F}_{\text{rep}}$ are two distinct and different types of forces with individual quantum parameters P_{a} and P_{r}, respectively. After re-arranging, equations (8,9) can be simplified and re-written as follows:

$$\mathbf{F}_{\text{att}} = -\frac{q_1 q_2}{4\pi\varepsilon_0 r^2}\,T_{\text{D}}\,P_{\text{a}}\left(\left(1-\frac{\boldsymbol{\delta}_1}{r}\right)^{-2} + \left(1+\frac{\boldsymbol{\delta}_2}{r}\right)^{-2}\right)\hat{\mathbf{r}} \tag{10}$$

$$\mathbf{F}_{\text{rep}} = +\frac{q_1 q_2}{4\pi\varepsilon_0 r^2} T_{\text{D}}\, P_{\text{r}} \left(1+\left(1-\frac{\boldsymbol{\delta}_1-\boldsymbol{\delta}_2}{r}\right)^{-2}\right)\hat{\mathbf{r}} \tag{11}$$

Thus, in the system of Figure 3 each charge is acted upon by almost identical attractive and repulsive interatomic forces that are superposed together, so much so they do largely but incompletely cancel each other out (SS-4.3).

4.2. Quantum Electric Coupling Mechanism

Equations (10,11) are pretty much the same as the classical EM force equation (3) except they are now multiplied by the following dimensionless force multipliers or parameters, attractive $\text{x}F_{\text{a}}$ and repulsive $\text{x}F_{\text{r}}$, that are proportional to P_{a}, P_{r} as well as shifts $\boldsymbol{\delta}_1$, $\boldsymbol{\delta}_2$ and distance r:

$$\text{x}F_{\text{a}} = -P_{\text{a}}\left(\left(1-\frac{\boldsymbol{\delta}_1}{r}\right)^{-2}+\left(1+\frac{\boldsymbol{\delta}_2}{r}\right)^{-2}\right) \qquad \text{x}F_{\text{r}} = P_{\text{r}}\left(1+\left(1-\frac{\boldsymbol{\delta}_1-\boldsymbol{\delta}_2}{r}\right)^{-2}\right) \tag{12}$$

If $P_{\text{a}} = P_{\text{r}} = 1$ and shifts $\boldsymbol{\delta}_1 = \boldsymbol{\delta}_2 = 0$, one obtains $\text{x}F_{\text{a}} = \text{x}F_{\text{r}} = 2$ (there are two atoms in Figure 3) and the absolute value of attractive and repulsive forces will be exactly identical and symmetric. However, the attractive and repulsive forces are two different kinds of competing QED forces the quantum parameters of which are not expected to have exactly the same values ($(P_{\text{a}} - P_{\text{r}}) > 0$) – see SS-5.3. This condition together with non-zero shift will cause the symmetry between the forces to break down and tips the balance in favour of attractive over repulsive forces. This asymmetry in force may form the basis of a new mechanism called the quantum electric coupling mechanism, which will play an important role in QEG where cancellation of almost identical but different types of forces takes place that leaves a small residue synonymous with the force of gravity – see SS-5.3.

4.3. Total Force between Two Atoms

Equations (10,11) are quite complete in that they now incorporate all the force parameters of electric, motion-dependent magnetic and quantum effects for the system shown in Figure 3. Remember that force multipliers (12) are dimensionless, so the unit of force in equations (10,11) remains the same (Newton) and that the force will revert back to the classical force if one lets the shifts $\boldsymbol{\delta}_1 = \boldsymbol{\delta}_2 = 0$ and $P_{\text{a}} = P_{\text{r}} = 1$. The two forces in (10,11) can now be added together to obtain the total net force F_{net}, as follows:

$$\mathbf{F}_{\text{net}} = \mathbf{F}_{\text{att}} + \mathbf{F}_{\text{rep}} \tag{13}$$

$$\mathbf{F}_{\text{net}} = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2} T_{\text{D}}\left(-P_{\text{a}}\left(\left(1-\frac{\boldsymbol{\delta}_1}{r}\right)^{-2}+\left(1+\frac{\boldsymbol{\delta}_2}{r}\right)^{-2}\right)+P_{\text{r}}\left(1+\left(1-\frac{\boldsymbol{\delta}_1-\boldsymbol{\delta}_2}{r}\right)^{-2}\right)\right)\hat{\mathbf{r}} \tag{14}$$

To simplify equation (14) we can expand the bracketed term using binomial expansion as shown in Appendix-D to obtain $\text{x}F_{\text{net}}$ (D-1), and then substitute this back in (14) to yield the following:

$$\mathbf{F}_{\text{net}} = -\frac{q_1 q_2}{2\pi\varepsilon_0 r^2} T_{\text{D}}\Bigg((P_{\text{a}}-P_{\text{r}})+\frac{1}{r}(P_{\text{a}}-P_{\text{r}})(\boldsymbol{\delta}_1-\boldsymbol{\delta}_2) + \frac{3}{2r^2}(P_{\text{a}}-P_{\text{r}})\left(\boldsymbol{\delta}_1^2+\boldsymbol{\delta}_2^2\right)+\frac{3}{r^2}(P_{\text{r}}\boldsymbol{\delta}_1\boldsymbol{\delta}_2)\Bigg) \tag{15}$$

We can identify two dimensionless terms inside the brackets of (15) as follows:

$$T_{\text{P}} = (P_{\text{a}} - P_{\text{r}}) \tag{16}$$

$$T_{\delta} = \frac{1}{r}(P_{\text{a}}-P_{\text{r}})(\boldsymbol{\delta}_1-\boldsymbol{\delta}_2)+\frac{3}{2r^2}(P_{\text{a}}-P_{\text{r}})\left(\boldsymbol{\delta}_1^2+\boldsymbol{\delta}_2^2\right)+\frac{3}{r^2}(P_{\text{r}}\boldsymbol{\delta}_1\boldsymbol{\delta}_2)\cdots \tag{17}$$

Terms T_{P} and T_{δ} are quite important terms as will be explained in more details in SS-5.3 and S-6. Using (16,17) we can re-write (15) as:

$$\mathbf{F}_{\text{net}} = -\frac{q_1 q_2}{2\pi\varepsilon_0 r^2} T_{\text{D}} \left(T_{\text{P}} + T_{\delta}\right) \hat{\mathbf{r}} \tag{18}$$

Equation (18) shows that the total EM force $\mathbf{F}_{\text{net}}$ between the two atoms (Figure 3) is proportional to the product q_1q_2 multiplied by a dimensionless factor T_{D} (T_{P} + T_{δ}) and divided by the square of distance and permittivity of free space. The bracketed term in (18) may alternatively be written as T_{P} ($1+T_{\delta}/T_{\text{P}}$). The concept behind equation (18) is quite interesting because it attributes the force to differences in quantum parameters that control electric interactions between atoms. As we will see below, equation (18) can be successfully applied to the force of gravity between large objects with results largely in line with Newton's and general relativity.

4.4. Force between Two Objects

For objects made up of large number of neutral atoms, one needs to determine the total charge and its effective position for each object. A uniform spherical shell of charge behaves, as far as external points are concerned, as if all its charge is concentrated at its centre in accordance with Gauss Law [10]. For example, in SS-3.3 we considered the electron cloud as a shell with a total charge concentrated at the centre of the shell. Here we shall deal with objects of spherically symmetric charge distributions comprising a number of concentric spherical shells n of uniformly-distributed charge Q_{sh1}, Q_{sh2}, Q_{sh3} ..... Q_{shn}, the effective charge of each shell is located at the centre. Each shell may comprise a number of materials (atoms) uniformly distributed over the shell. Applying the principle of superposition, one can add the charges of all these shells to determine the total object charge Q positioned at the centre of the object, as follows:

$$Q = Q_{\text{sh1}} + Q_{\text{sh2}} + Q_{\text{sh3}} \cdots + Q_{\text{sh}n} = \sum_{i=1}^{n} Q_{\text{sh}i} \tag{19}$$

Note that Newton used a similar method (shell theorem) for treating mass of spherically symmetric bodies [15]. Therefore, for spherically symmetric objects 1, 2 of total charge Q_1, Q_2 each distributed over spherically symmetric uniform shells, one can treat charge Q_1, Q_2 as point charges located at the centre of objects 1, 2, respectively. Charges Q_1, Q_2 represent the absolute value of total positive or negative charge in the objects. The force $\mathbf{F}_{\text{net}}$ between the two objects can be determined by replacing atomic charge q_1, q_2 in (18) with object charge Q_1, Q_2, respectively, as follows:

$$\mathbf{F}_{\text{net}} = -\frac{1}{2\pi\varepsilon_0} \frac{Q_1 Q_2}{r^2} T_{\text{D}} \left(T_{\text{P}} + T_{\delta}\right) \hat{\mathbf{r}} \tag{20}$$

As will be explained in SS-5.3, the terms T_{P} and T_{δ} play two different and quite important roles in the force equations (18,20). Basically, the T_{P} term dominates at large r-values which can control the force between large objects, while the contribution of the T_{δ} term increases at smaller r-values. Since T_{D} (T_{P} + T_{δ}) is dimensionless, the unit of force in (20) is Newton as in Coulomb's Law.

5. Force from Object Mass

In general, charges Q_1, Q_2 in equation (20) cannot be easily determined, particularly when each object is composed of different types of atoms. In this section we shall determine object charge from its mass and use this to determine the force directly from mass. To do that, we need to determine the atomic charge and the total number of atoms per unit mass.

5.1. Charge–Mass Relations

In the standard model of particle physics, the atomic charge includes electrons as well as nucleons or quarks charge and should, therefore, depend on the atomic number Z and mass number (nucleons number) A. One can define an atomic charge factor A_q for a neutral atom such that when multiplied by the fundamental electric charge e, A_q will yield the positive or negative charge contained in the atom, as follows:

$$q = A_q e \tag{21}$$

As shown in Appendix-E, the atomic charge factor A_q can be calculated as follows:

$$A_q = \frac{2}{3}\left(A+Z\right) \tag{22}$$

For example, the charge in a Carbon atom with Z=6 and A=12 can be calculated from (22) as:

$$q_{\mathrm{Carbon12}} = \frac{2}{3}\left(A+Z\right)e = \frac{2}{3}\left(12+6\right)e = 12e \tag{23}$$

In order to determine the number of atoms N in mass m, one should recall that what matters in QEG is the quantity of "charge" contained in m. Mass m can be determined by weighing an object on a scale (m = **F**/**g**), i.e. by measuring Earth's force of gravity pulling on m. In QEG the latter force arises from the electrical interactions between Earth and the charge contained in each and every atom in m, as defined by A_q. From QEG's perspective (see SS-5.2), the weight of mass m can be viewed as a measure of how much effective "charge-related" pull the object possesses. Accordingly, in order to determine the number of atoms N in mass m one needs to determine how many units of "A_q" are contained in mass m, as follows:

$$N = N_A \frac{m}{A_q} \tag{24}$$

where N_A=6.022 x 10^{26} atoms/kg (or atoms/mole) is the Avogadro's Constant. Constant N_A is also related to the unified atomic mass unit u, u = 1/N_A= 1.6605 x 10^{-27} kg, from which one may alternatively use $N = m/(\mathrm{u}A_q)$. The charge Q contained in mass m can now be determined from equations (21,24), as:

$$Q = qN = A_q e N_A \frac{m}{A_q} = e N_A m \tag{25}$$

Note that the atomic charge factor A_q appears in both numerator and denominator of (25) and so cancels out, which simplifies charge calculation directly from mass irrespective of object composition. It is clear from (25) that mass can be viewed as an electrical entity which may be referred to as the (equivalent) "electric mass". It is interesting to note from (25) that the charge and mass are intimately connected and that the ratio of charge/mass (Q/m) is a fixed quantity equals to the Faraday constant $F = eN_A = e/\mathrm{u}$ = 9.6485 x 10^7 (NIST/CODATA). For a spherically symmetric uniform shell of mass m_{sh} one can determine the shell charge Q_{sh} from (25) as:

$$Q_{sh} = e N_A m_{sh} \tag{26}$$

For a spherically symmetric object comprising a number of uniform concentric shells n of masses m_{sh1}, m_{sh2}, m_{sh3}....m_{shn}, one can apply the principle of superposition and substitute (26) in (19) to determine total object charge Q from object mass m, as follows:

$$Q = \sum_{i=1}^{n} Q_{shi} = e N_A \left(m_{sh1} + m_{sh2} + m_{sh3} \cdots + m_{shn}\right) = e N_A \sum_{i=1}^{n} m_{shi} = e N_A m \tag{27}$$

In a sense equation (27) combines the shell theorems of Gauss [10] and Newton [15] together. The total object charges Q_1, Q_2 located at the centre of objects 1, 2 can now be determined from total object masses m_1, m_2, respectively, using the charge-mass relation (27) as follows:

$$Q_1 = e N_A m_1 \qquad Q_2 = e N_A m_2 \tag{28}$$

5.2. Quantum Electric Gravity Force between Objects

We can now express the force in terms of mass by substituting Q_1 & Q_2 from equations (28) in equation (20) to obtain the total net force F_{net}, as follows:

$$\mathbf{F}_{\text{net}} = -\frac{e^2 N_{\text{A}}^2}{2\pi\varepsilon_0} \frac{m_1 m_2}{r^2} T_{\text{D}} \left(T_{\text{P}} + T_\delta\right) \hat{\mathbf{r}} \tag{29}$$

Equation (29) describes how quantum electric phenomena can give rise to a net attractive force between the masses of two objects, with properties and features synonymous with the force of gravity. One may therefore refer to this force as Quantum Electric Gravity ($\mathbf{F}_{\text{QEG}}$) and re-write (29) as:

$$\mathbf{F}_{\text{QEG}} = \mathbf{F}_{\text{net}} = -\frac{e^2 N_{\text{A}}^2}{2\pi\varepsilon_0} T_{\text{D}} \left(T_{\text{P}} + T_\delta\right) \frac{m_1 m_2}{r^2} \hat{\mathbf{r}} \tag{30}$$

The force in (30) may be rewritten in an alternative and more familiar form, i.e. similar to that of Newton's Law of Gravitation, as follows:

$$\boxed{\mathbf{F}_{\text{QEG}} = -G_{\text{QE}} \frac{m_1 m_2}{r^2} \hat{\mathbf{r}}} \tag{31}$$

where G_{QE} represents a new parameter, the quantum electric gravitational parameter, with roots firmly established in quantum mechanics and defined as:

$$G_{\text{QE}} = \frac{e^2 N_{\text{A}}^2}{2\pi\varepsilon_0} T_{\text{D}} \left(T_{\text{P}} + T_\delta\right) \ \rightarrow \ \left(\equiv G\right) \tag{32}$$

Therefore, QEG introduces corrections to G and replaces it with the new G_{QE}. Equation (32) indicates that while largely similar to G, G_{QE} can vary under some conditions and/or due to nonlinear effects. The force in (30,31) has some quite interesting aspects in that, in addition to the motion-dependent term T_{D}, it has two scale-dependent terms; T_{P} (16) and T_δ (17), that can be determined experimentally (S-6). Since parameters T_{D}, T_{P} and T_δ are all dimensionless, the units of G_{QE} should match that of Newton's gravitational constant G:

$$\frac{\text{N}\,\text{m}^2}{\text{C}^2} \frac{\text{C}^2}{\text{kg}^2} = \frac{\text{N}\,\text{m}^2}{\text{kg}^2} \equiv G \tag{33}$$

It is interesting to observe that equations (30,31) combine the hitherto irreconcilable theories of Newton's and general relativity on the one hand, and quantum mechanics/physics on the other. QEG achieves all that despite the heretofore prevailing notion that the theories of Newton's and general relativity are different and otherwise seemingly unrelated paradigms to the disciplines of QM/EM on which QEG is founded. Equation (30) can be alternatively written as:

$$\mathbf{F}_{\text{QEG}} = -\frac{1}{2\pi\varepsilon_0} \left(\frac{e}{\text{u}}\right)^2 T_{\text{D}} \left(T_{\text{P}} + T_\delta\right) \frac{m_1 m_2}{r^2} \hat{\mathbf{r}} \tag{34}$$

5.3. Gravitational Parameter G_{QE} – Inverse Square Law

We can observe from (32) that G_{QE} is proportional to T_{D}, T_{P} and T_δ terms. The T_{D} term does not depend on r (SS-3.1). The T_{P} term (16) depends on the difference in quantum parameters ($P_{\text{a}} - P_{\text{r}}$) and makes the force dependent on the inverse square of distance. The T_δ term (17) comprises an infinite number of terms, and depends on shifts $\boldsymbol{\delta}_1$ and $\boldsymbol{\delta}_2$, on $1/r^{\text{n}}$ and also on quantum parameters P_{a} and P_{r}. T_δ is expected to have negligible contribution to the force between objects, but become progressively more significant at smaller r-values, especially at interatomic and intermolecular scales. Appendix-C shows that since the shift itself varies as $1/r^3$, the T_δ term should vary as $1/r^4$ and higher. When multiplied by $1/r^2$ outside the brackets in (30), T_δ would make the force vary with $1/r^{\text{n}}$, where n =6 and higher.

It is well established both experimentally and observationally that the force of gravity between two objects ($r >> 1$) follows inverse square law. For the QEG force in (30-31) to follow inverse square law, the following conditions must hold:

i) The difference between quantum parameters ($P_a - P_r$) must have a value greater than zero, i.e. $T_P = (P_a - P_r) > 0$ or $P_a/P_r > 1$. This is because if $P_a = P_r$, then $T_P = 0$, $T_\delta = 3P_r\boldsymbol{\delta}_1\boldsymbol{\delta}_2/r^2$ and the force will depart away from inverse square law.

ii) The value or contribution of T_δ should be negligible in comparison to that of T_P – which is true for gravity between objects ($r >> 1$)

iii) Parameters P_a, P_r are largely independent of r and that if such a dependency should exist, it is unlikely to be significant

Based on these conditions, for QEG force between objects such as Earth-Moon, the T_δ term may be neglected in practice and equation (30) may be re-written as:

$$\mathbf{F}_{\mathrm{QEG}} \approx -\frac{e^2 N_A^2}{2\pi\varepsilon_0}\, T_D\, T_P\, \frac{m_1 m_2}{r^2}\, \hat{\mathbf{r}} \tag{35}$$

which is in line with Newtonian gravity ($T_D = 1$). In S-6 below we shall determine the value of T_P from experiment. Although we have derived the terms T_P, T_δ, T_D, $\boldsymbol{\delta}$ and α in one dimension to simplify the analyses, one can use appropriate mathematical operators and techniques (Tensors ...) to derive appropriate more accurate 3D equivalents for these parameters and their individual sub-parameters. More accurate T_δ formula may be obtained by time-averaged shift calculations in 3D space using quantum mechanics.

5.4. Quantum Electric Gravity from Charge & Mass

Equations (25-32) can be combined to derive some interesting and versatile ways to calculate $\mathbf{F}_{\mathrm{QEG}}$, namely from the mass of one object and the charge of the other or vice versa, as follows:

$$\mathbf{F}_{\mathrm{QEG}} = -\frac{e N_A}{2\pi\varepsilon_0}\, T_D\, (T_P + T_\delta)\, \frac{Q_1 m_2}{r^2}\, \hat{\mathbf{r}} = -\frac{G_{QE}}{e N_A}\, \frac{Q_1 m_2}{r^2}\, \hat{\mathbf{r}} \tag{36}$$

Equations (36) may be quite useful in determining $\mathbf{F}_{\mathrm{QEG}}$ on any form of charge, potentially including a postulated effective or virtual charge associated with EM radiation. In equation (36) one can also express the acceleration of gravity $\mathbf{g}$ in terms of charge by letting $\mathbf{g} = \mathbf{F}_{\mathrm{QEG}} / m_2$.

6. Experimental Determination of G_{QE}

For over 300 years since its inception by Isaac Newton, the gravitational "constant" G had been shrouded with mysteries such as: what's the origin and cause of G, should it have some dependency on distance r, is it really a constant or does it change over time. It is interesting that QEG can shed some light on these issues and express G in terms of more fundamental physical parameters and entities. In Henry Cavendish's or like experiments it was determined that the proportionality constant in Newton's gravity (G) should have the value $G = 6.67259 \times 10^{-11}$. QEG can qualify this and replaces G with the quantum electric gravitational parameter G_{QE} (32) as follows:

$$G_{QE} = \frac{e^2 N_A^2}{2\pi\varepsilon_0}\, T_D\, (T_P + T_\delta) \equiv G \tag{37}$$

Since there was no velocity involved in Cavendish's experiment, we can assume $T_D = 1$ to obtain:

$$\frac{e^2 N_A^2}{2\pi\varepsilon_0}\, (T_P + T_\delta) = G \tag{38}$$

$$(T_P + T_\delta) = \frac{2\pi\varepsilon_0}{e^2 N_A^2}\, G \tag{39}$$

$$(T_P + T_\delta) = 3.9875 \times 10^{-37} \approx 4 \times 10^{-37} \tag{40}$$

Equation (40) can be substituted in (32) to write the quantum electric parameter G_{QE} (as determined from Cavendish's experiment) in general, as follows:

$$G_{\mathrm{QE}} = \frac{e^2 N_{\mathrm{A}}^2}{2\pi\varepsilon_0} 4\times10^{-37} T_{\mathrm{D}} = 6.67259\times10^{-11} T_{\mathrm{D}} \tag{41}$$

As explained in SS-5.3, the T_δ term does not on its own support the experimentally-verified inverse square law observations, because T_δ makes the force proportional to higher power of $1/r^n$ terms where n > 2 (17). In order to accurately determine the value of T_P one needs to know the value or contribution of T_δ to the total force at the distance scale in Cavendish's experiment, because the T_δ term increases at smaller distances. If one were to assume the value of T_δ in the experiment to be small in comparison to T_P, one may then be able to approximate T_P as $T_P \sim 4\text{x}10^{-37}$.

The T_δ term may be assessed from interatomic and intermolecular forces, like that of van der Waals, London Dispersion forces and Lennard-Jones Potential/Force function, which forces are well established [16,17].

It remains to be seen whether or not T_P may have some other dependencies which, if any, may introduce further nonlinearity in the quantum gravitational parameter G_{QE}. Note that it should be possible to derive parameters P_a, P_r, δ_1, δ_2, T_P and T_δ from EM and QM/QED principles [18].

7. Summary of QEG's Features

As explained above, QEG is compatible with electromagnetism, quantum mechanics and special relativity, and should potentially fulfil the essential requirements of a quantum theory of gravity.

While in line with Newton's law of gravitation, QEG's gravitational parameter G_{QE} departs away from Newton's via its velocity term T_D, shift term T_δ and nonlinear effects. In the limit of zero velocities and large r values ($T_\delta \sim 0$) QEG reduces to Newtonian gravity.

Through its T_P and T_δ terms, QEG is potentially more compatible with the other fundamental forces of nature, more so than Newton's and GR and may eventually lead to a viable theory of everything (TOE).

In contrast to all other theories of gravity including Newton's, general relativity and string theory, QEG provides a more plausible and intuitive mechanism for gravity.

QEG's formulae provide ways of calculating force from charge (20), from mass (30-31) and from both charge and mass (36).

The forces in QEG are communicated by the exchange of messenger particles in the form of QED's virtual particles and photons. It is thought that this should alleviate the need to postulate the existence of the illusive graviton.

8. Discussion

1) The QEG force equations can be viewed as having two scale-dependent terms. A large distance scale or a macro-scale embodied in the T_P term (16) and a small distance scale or a micro-scale embodied in the T_δ term (17). Both terms contribute to the total force by varying amounts. For gravity between objects (e.g. Earth-Moon) the distances are relatively large in which case the micro-scale term diminishes ($T_\delta \sim 0$) and the macro-scale term dominates the force equation. For small distances such as when $r << 1$ it is expected that the contribution of the micro-scale term should increase significantly. In the latter, the force is proportional to $1/r^n$ where n =6 or 7 (see SS-3.3 and Appendix–C), which can potentially describe interatomic forces including van der Waals forces between atoms

and molecules that varies as $1/r^7$[17]. It is envisaged that the micro-scale term may be applicable down to even smaller scales like those of nuclear forces that bind nucleons together, where its contribution is expected to be much larger.

2) The neutrons are already included in the QEG force equation as charge constituent of mass – see SS-5.1. According to the standard model of particle physics, the neutrons are composed of up and down quarks of +2/3 *e* and –2/3 *e* charge, respectively. Scientists have experimentally observed that while electrically neutral on the whole, neutrons do have a positive charge core on the inside and a negative charge on the surface [19,20]. The neutron is stable only inside atoms otherwise it decomposes into a proton and an electron (and antineutrino) outside the atom within < 15 minutes. One can view neutrons as charge-dual entities similar to neutral atoms (Appendix-B).

3) As explained above, the QEG force varies by discrete steps due to interactions between atomic charge entities and virtual particles/photons. Normally the resulting discrete steps in the force are difficult to detect in large objects. However, under certain appropriate conditions experiments can be conducted to monitor and detect the resulting stepwise discrete incremental motions (variations in *r*) of individual or a stream of charge-dual particles. In one experiment [21] it was established that the gravitational quantum bound states of neutrons had been experimentally verified, which proves that neutrons falling under gravity do not move vertically in a continuous manner but rather jump from one height to another, as predicted by quantum theory [21]. The latter may be considered as experimental evidence in support of QEG.

4) The motion-dependent factor T_D (SS-3.1) is another departure from Newton's (NLG). In one example supported by astronomical observations, inner planets experience slightly larger forces than do outer planets, such as in the case of the perihelion advance of Mercury. One reason for this is that inner planets travel at higher velocities than do outer planets, which alters T_{Dt} in (4) and increases the force. Another possible reason may come from the increased value of T_δ (17) due to the reduced Planet-Sun distance, and/or some nonlinear effects. The tangential velocity component (Figure 1) covers most situations encountered in practice, such as in circular or near-circular motions of planets around stars (Sun) and the orbital motion of binary star systems. However, for other and more complex arrangements, e.g. where the velocities may point along different directions, one would need to use Lorentz Transformations in 3D space [5] to derive appropriate relativistic formula for T_D. For other objects such as fast rotating stars, neutron stars, quasars and magnetars, one may follow the same methodology above to derive appropriate T_D formula, taking into account the different velocities of the various parts within each object.

5) The quantum electric gravitational parameter G_{QE} may possibly have another quite interesting behaviour, namely that of temperature effects. For example, the shift (δ) arising from deformation polarizability α is a function of atomic radius *a*, i.e. $\alpha = 4\pi\varepsilon_0 a^3$ [11,12], and the effective atomic radii as well as interatomic distances depend on temperature as observed in the phenomenon of thermal expansion [22]. From that one would expect to see some possible temperature sensitivity in G_{QE}. The temperature effect is expected to increase at smaller *r*-values, i.e. it is likely to be comparatively higher at the micro-scale than at the macro-scale.

6) Most phenomena relating to gravitational interactions with light predicted by general relativity had already been verified experimentally, including gravitational light bending, red shift, gravitational lensing, time dilation and frequency shift. In QEG most of these phenomena should come as no surprise, given that both QEG and light (EM radiation) are founded on common fundamental electromagnetic and QED principles, where there is stronger likelihood of inter-coupling. For example, in gravitational light bending the lower part of light ray should experience slightly stronger gravity and should be slightly retarded (phase-shifted) relative to the upper part. This is a similar situation to Young's double-slit optical experiment except that, in this case, light entering the bottom slit will be somewhat slightly retarded in comparison to the top part of beam. This latter action should

result in an additional downward beam deflection or "optical" twisting in accordance with Huygens principle [23]. In the phenomenon of gravitational red shift, light's energy and frequency decrease when moving into a region of lower gravitational field and thus gets red-shifted, while it gets blue-shifted when moving into a region of higher gravitational field.

7) For objects moving at radial velocities (along r) such as in the example shown in Figure 4, comprising a source charge q_1 moving along r at velocity $\mathbf{v}_1$, and a stationary test charge q_2, one can derive the appropriate radial velocity term T_{Dr} using Lorentz Transformations. The term T_{Dr} can be written as [5]:

$$T_{\mathrm{Dr}} = \frac{1}{\gamma^2} = \left(1 - \frac{\mathbf{v}_1^2}{c^2}\right) \tag{42}$$

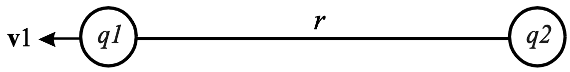

Figure 4 - EM forces between two charges – radial velocity

By substituting (42) in (32) and letting $T_{\mathrm{D}} = T_{\mathrm{Dr}}$ one can write the G_{QE} equation as follows:

$$G_{\mathrm{QE}} = \frac{e^2 N_{\mathrm{A}}^2}{2\pi\varepsilon_0}\left(1 - \frac{\mathbf{v}_1^2}{c^2}\right)\left(T_{\mathrm{P}} + T_{\delta}\right) \tag{43}$$

which indicates that gravity in QEG can be influenced by object's radial velocity. Substituting (43) in (31) will make the force decrease as $\mathbf{v}_1$ increases and continues to decrease all the way down to zero (i.e. no gravity) at $\mathbf{v}_1 = c$. If $\mathbf{v}_1 > c$, the bracketed term in (43) becomes negative which will make gravity change sign and become "repulsive". Equation (43) is expected to have potential implications for the expansion, dynamics and evolution of the universe [24].

8) The simple Dipole Atomic model (SS-3.3) intuitively helped explain the basic principles and general trends of force behaviour. Ideally one should use a full 3D atomic model to obtain more accurate results, but this would have unnecessarily complicated the analysis for the average reader and made it beyond the scope of this paper. A drawback of the Dipole Atomic model was its reduced repulsive force behaviour near interatomic distances, where it should get progressively higher in line with the standard van der Waals and the Lennard-Jones potential and force functions [16]. As a good alternative, however, one may instead use the more representative Tripole Atomic model in which the negative charge is split in two parts one on either side of nucleus. This should enhance the repulsive component between electron clouds as atoms come too close and, therefore, should be more in line with van der Waals forces [25].

9) From QEG's equations presented in this paper, one would expect the QEG force to be valid as long as the structure of charge-dual entities is preserved. One, therefore, wonders about the ultimate form of matter existing at the extremely high levels of gravity found inside very massive stars, and whether it would be in the form of neutrons, quarks or some other unknown forms. Initial investigation [25] appears to suggest that, providing the structure and form of charge-dual entities were to be preserved, the force of gravity inside these massive objects may reach a certain limit imposed by the smallest and most compact attainable form of charge-dual entities and the distances between them. From our current knowledge it is probable that this limit may lie at the level of neutrons (neutron stars). However, if the form of charge-dual entities were to ultimately breakdown, QEG would then vanish to unmask the raw EM forces into the realm of the presently unknown world.

9. Conclusion

Quantum electric gravity is a radically different theory that relies on electromagnetic and quantum electrodynamics foundations to derive and formulate a proposed quantum theory of gravity substantially in line with Newton's and general relativity. QEG introduces quantum electric corrections to the gravitational constant *G* and predicts its nonlinear behaviour at high field intensities. In addition to the force of gravity between objects, QEG can be extended to describe interatomic and intermolecular forces through its T_δ term, with which it predicts such forces to be proportional to higher power 1/r terms and in line with observations and experiments. QEG potentially fulfils many of the essential requirements of a quantum theory of gravity. It is expected that the new understandings brought about by QEG should provide flexible tools and concepts more able to cope with and handle contemporary intractable gravitational and cosmological issues. It is also hoped that QEG may provide the missing link between gravity and the other fundamental forces of nature, which should bring the goal of theory of everything closer than have been possible. Lying dormant for over three centuries, the origin and character of the gravitational constant *G* are beginning to unravel, for QEG is now pointing to its quantum electric origin.

Appendix–A: QED's Force Mediation by Virtual Particles

Quantum Electrodynamics (QED), developed by Feynman [6] and others, extends quantum mechanics to the EM Field. QED is a quantum field theory, and is one of the most precise physical theories that have been extensively confirmed experimentally as in the cases of the Gyromagnetic ratio of the Electron [7], the Lamb's shift and Casimir effect [8]. In QED, virtual particles such as electron-positron pairs can be created by "borrowing" energy ΔE from the vacuum for a brief period of time Δt in accordance with the Heisenberg Uncertainty Principle $\Delta E\,\Delta t \geq \hbar/2$. But shortly afterwards they recombine and annihilate to "pay back" their borrowed energy, and this incessant process of creation and annihilation goes on forever. In QED the EM field is quantised and is represented by particles called photons. QED explains how charge particles (fermions) interact by the exchange of messenger particles or photons (bosons) [7,8,9]. For electric and magnetic forces QED describes such interactions as exchange of force-carrier particles in the form of temporary or virtual particles or virtual photons. These particles are "virtual" because they do not obey energy/momentum relations as do real particles. Unlike real photons which transport EM wave, virtual photons mediate the electric and magnetic forces [7,8]. QED also addressed the ambiguous concept of action-at-a-distance as originally envisaged by Newton, and replaced it with the exchange of messenger particles between charge entities. In addition, the quantum vacuum is teeming with virtual particle pairs such as electron-positron pairs that are constantly being created and annihilated. These virtual particle pairs will get polarized when in the neighbourhood of charge entities, through a process known as vacuum polarization [26].

Appendix–B: Atoms as Charge-Dual Entities

Since neutral atoms contain equal amount of positive and negative charge, one may consider them as charge-dual entities. A summary of the properties of charge-dual entities includes:

i) The most striking feature is that they can interact with other charge entities via two types of electromagnetic/QED fields and forces: attractive and repulsive. So, they can exert push and pull forces on all other charge entities, whether single or charge-dual entities.
ii) The absolute magnitudes of positive and negative charge are identical.
iii) The opposite direction fields and forces in (i) will almost completely cancel each other out and, on average, portray atoms as electrically neutral.
iv) They also include some apparently "neutral" entities like neutrons, which do have internal charge structure capable of interacting with fields and forces.
v) They are the fabric of the universe.

Appendix–C: Dipole Electric Field

In classical electromagnetism, the field of an electric dipole of moment **p** is given by (see [14] for notations and details):

$$\mathbf{E}(\mathbf{r}) = \frac{\mathbf{p}\cos\theta}{2\pi\varepsilon_0 r^3}\,\hat{\mathbf{r}} + \frac{\mathbf{p}\sin\theta}{4\pi\varepsilon_0 r^3}\,\hat{\boldsymbol{\theta}}$$

Appendix–D: Binomial Expansion

$$\mathrm{x}F_\mathrm{a} = -P_\mathrm{a}\left(\left(1-\frac{\delta_1}{r}\right)^{-2} + \left(1+\frac{\delta_2}{r}\right)^{-2}\right) = -P_\mathrm{a}\left(1+2\frac{\delta_1}{r}+3\left(\frac{\delta_1}{r}\right)^2+\cdots 1-2\frac{\delta_2}{r}+3\left(\frac{\delta_2}{r}\right)^2+\cdots\right)$$

$$\mathrm{x}F_\mathrm{r} = P_\mathrm{r}\left(1+\left(1-\frac{\delta_1-\delta_2}{r}\right)^{-2}\right) = P_\mathrm{r}\left(1+1+2\left(\frac{\delta_1-\delta_2}{r}\right)+3\left(\frac{\delta_1-\delta_2}{r}\right)^2+\cdots\right)$$

$$\mathrm{x}F_\mathrm{a} = -P_\mathrm{a}\left(2+\frac{2}{r}(\delta_1-\delta_2)+\frac{3}{r^2}\left(\delta_1^2+\delta_2^2\right)+\cdots\right)$$

$$\mathrm{x}F_\mathrm{r} = +P_\mathrm{r}\left(2+\frac{2}{r}(\delta_1-\delta_2)+\frac{3}{r^2}\left(\delta_1^2-2\delta_1\delta_2+\delta_2^2\right)+\cdots\right)$$

$$\mathrm{x}F_\mathrm{net} = -\mathrm{x}F_\mathrm{a}+\mathrm{x}F_\mathrm{r} = -2(P_\mathrm{a}-P_\mathrm{r}) - \frac{2}{r}(P_\mathrm{a}-P_\mathrm{r})(\delta_1-\delta_2) - \frac{3}{r^2}(P_\mathrm{a}-P_\mathrm{r})\left(\delta_1^2+\delta_2^2\right) - \frac{6}{r^2}(P_\mathrm{r}\delta_1\delta_2)$$

$$\mathrm{x}F_\mathrm{net} = -2\left((P_\mathrm{a}-P_\mathrm{r})+\frac{1}{r}(P_\mathrm{a}-P_\mathrm{r})(\delta_1-\delta_2)+\frac{3}{2r^2}(P_\mathrm{a}-P_\mathrm{r})\left(\delta_1^2+\delta_2^2\right)+\frac{3}{r^2}(P_\mathrm{r}\delta_1\delta_2)\right) \quad (\mathrm{D}-1)$$

$$\mathrm{x}F_\mathrm{net} = -2(P_\mathrm{a}-P_\mathrm{r})\left(1+\frac{1}{r}(\delta_1-\delta_2)+\frac{3}{2r^2}\left(\delta_1^2+\delta_2^2\right)+\frac{3}{r^2}\left(\frac{P_\mathrm{r}}{(P_\mathrm{a}-P_\mathrm{r})}\right)\delta_1\delta_2\right)$$

Appendix–E: Atomic Charge Factor $A_\mathbf{q}$ – Neutral Atoms

$$\text{Electrons} \rightarrow Z$$

$$\text{Proton quarks} \rightarrow (2u,d)Z$$

$$\text{Neutron quarks} \rightarrow (u,2d)(A-Z)$$

$$A_q\,(\text{positive entities}) = 2u\,Z+u(A-Z) = \left(\left(\frac{2}{3}+\frac{2}{3}\right)Z+\frac{2}{3}(A-Z)\right) = \frac{2}{3}(A+Z)$$

$$A_q\,(\text{negative entities}) = Z+d\,Z+2d(A-Z) = \left(\left(1+\frac{1}{3}\right)Z+\left(\frac{1}{3}+\frac{1}{3}\right)(A-Z)\right) = \frac{2}{3}(A+Z)$$

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